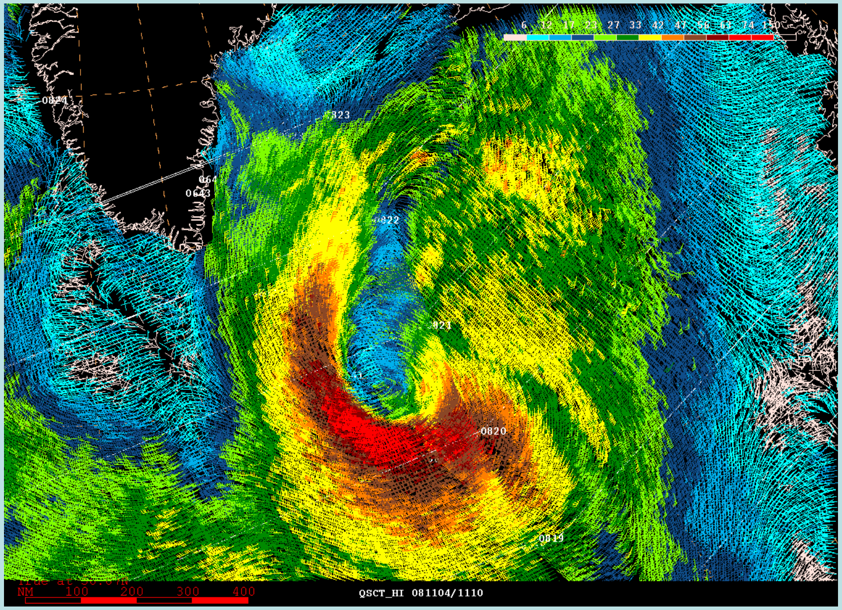
Extreme Extra-tropical Cyclone Climatology

Joseph M. Sienkiewicz

NOAA/NWS Ocean Prediction Center

Khalil Ahmad, Gregory McFadden, Zorana Jelenak,

Paul Chang, Michael Brennan, Joan Von Ahn



1979 – President’s Day Blizzard

DAILY NEWS

New York, Tuesday, February 20, 1979

SNEAK STORM CRIPPLES CITY

Snow in area up to 17 inch

FORECASTERS GOOF AGAIN

SAVE ON TAXE

Sylvia Porter begins an eleven part series

Page 4

BOSART 1559

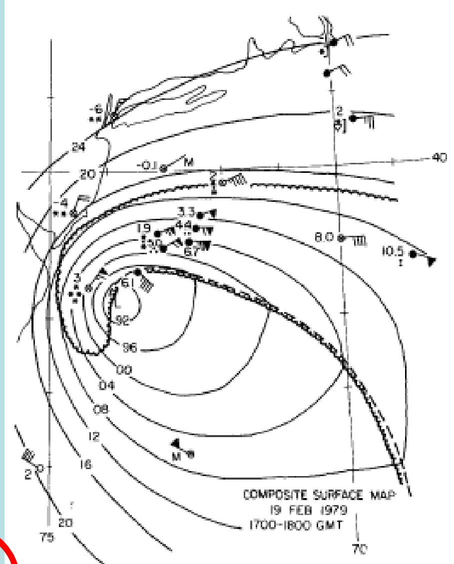
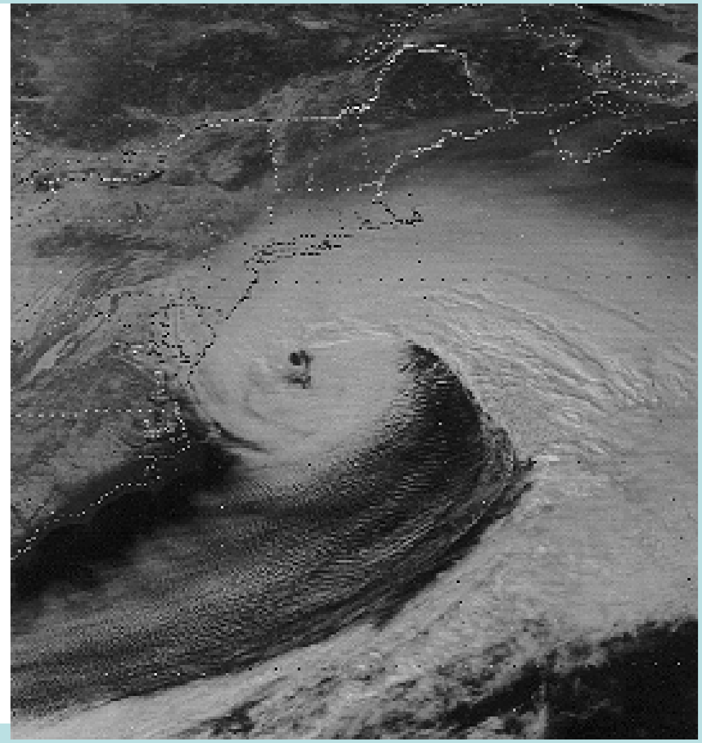


FIG. 18. Composite surface sectional map for 1700–1800 GMT 19 February 1979. Winds in m s^{-1} as per Fig. 1 plotting convention, isobars in mb, temperatures in °C with conventional plotting and analysis. Escolloped lines enclose convective region shown in Fig. 16.



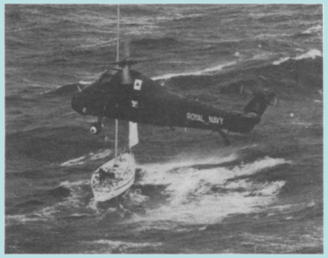
-Poorly predicted in Washington, DC

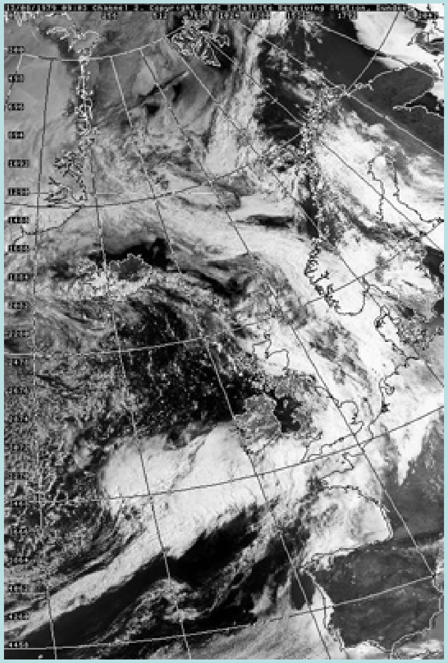
-Rapid intensification as exited coast

-Highlighted limitations of NWP

1979: “Freak storm hits yacht race”

…BBC News

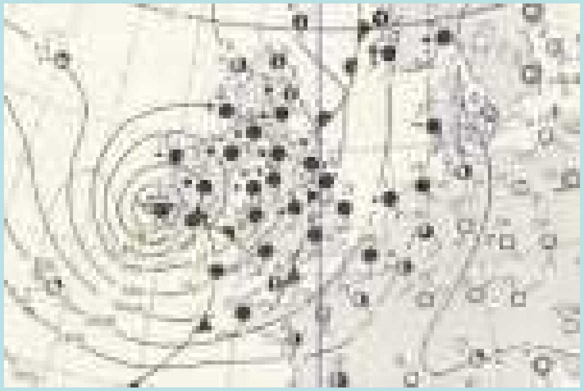




“The race was hit by a violent Force 10 storm that swept across the North Atlantic and into the southern Irish Sea, catching forecasters almost completely unawares”.

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"

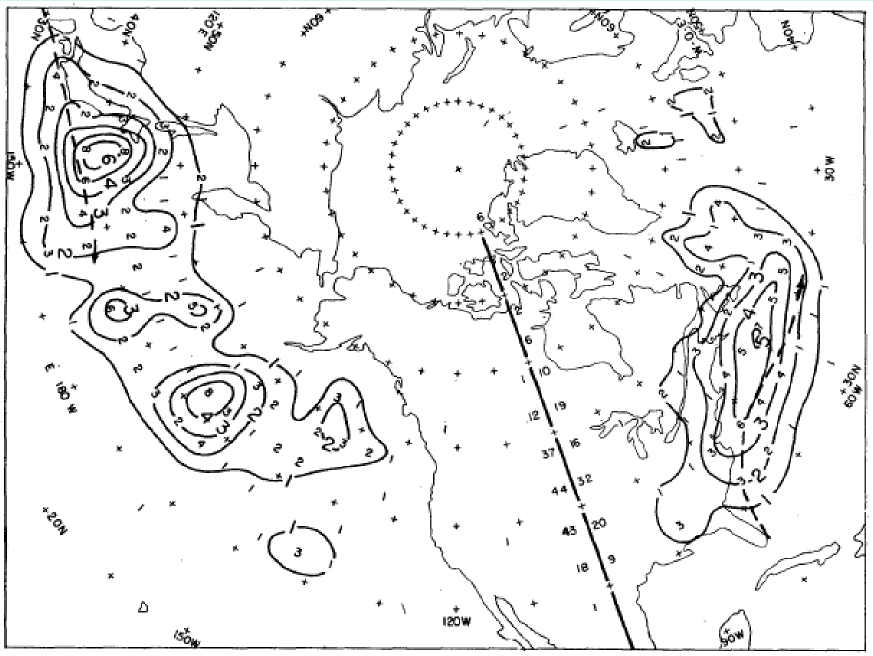


FIG. 3. Distribution of bomb events during three cold seasons. Raw non-zero frequencies appear in each 5° × 5° quadrilateral of latitude and longitude. Isopleths represent smoothed frequencies, obtained as one-eighth of the sum of four times the raw central frequency plus the sum of the surrounding raw frequencies. The column of numbers to the left and right of the heavy line along longitude 90°W represent, respectively, the normalized frequencies for each 5° latitude belt in the Pacific and Atlantic regions, using a normalization factor of (cos42.5/cosφ). Heavy dashed lines represent the mean winter position of the Kuroshio and the Gulf Stream.

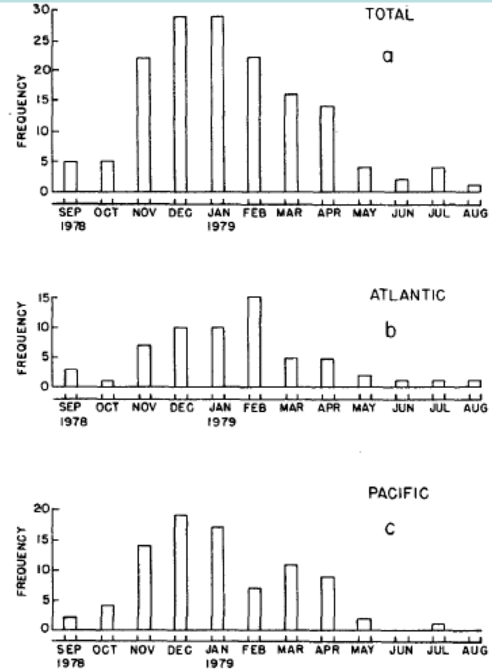


FIG. 9. Monthly bomb frequencies for 1978–79 season.

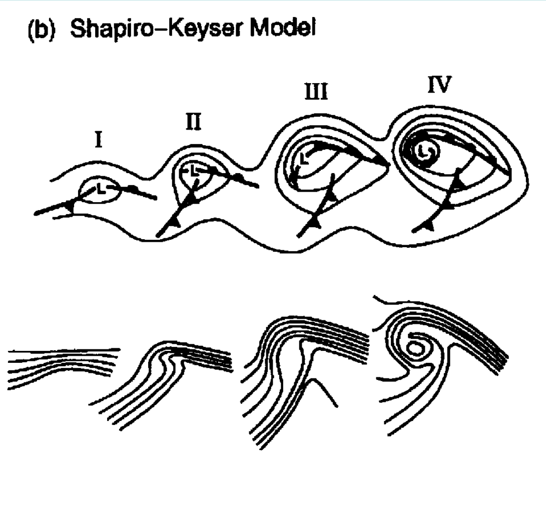
Triggered two field campaigns – Genesis of Atlantic Lows Experiment (GALE)

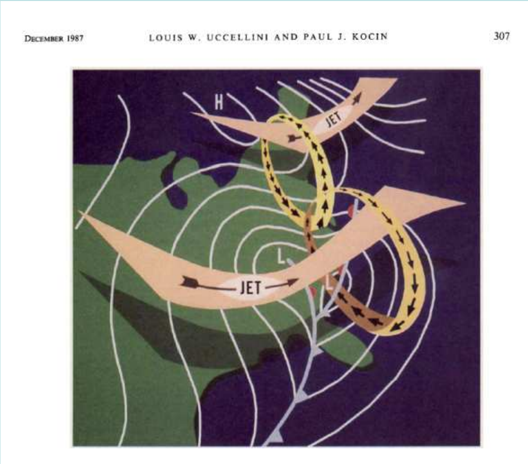
- Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA)

Linked SST gradient to rapid cyclogenesis

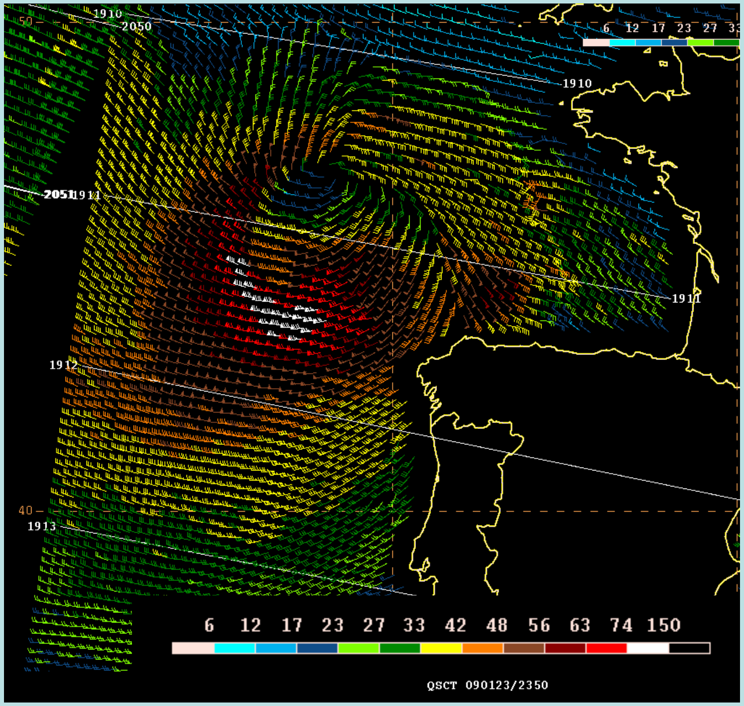
GALE and ERICA focus

- 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)**



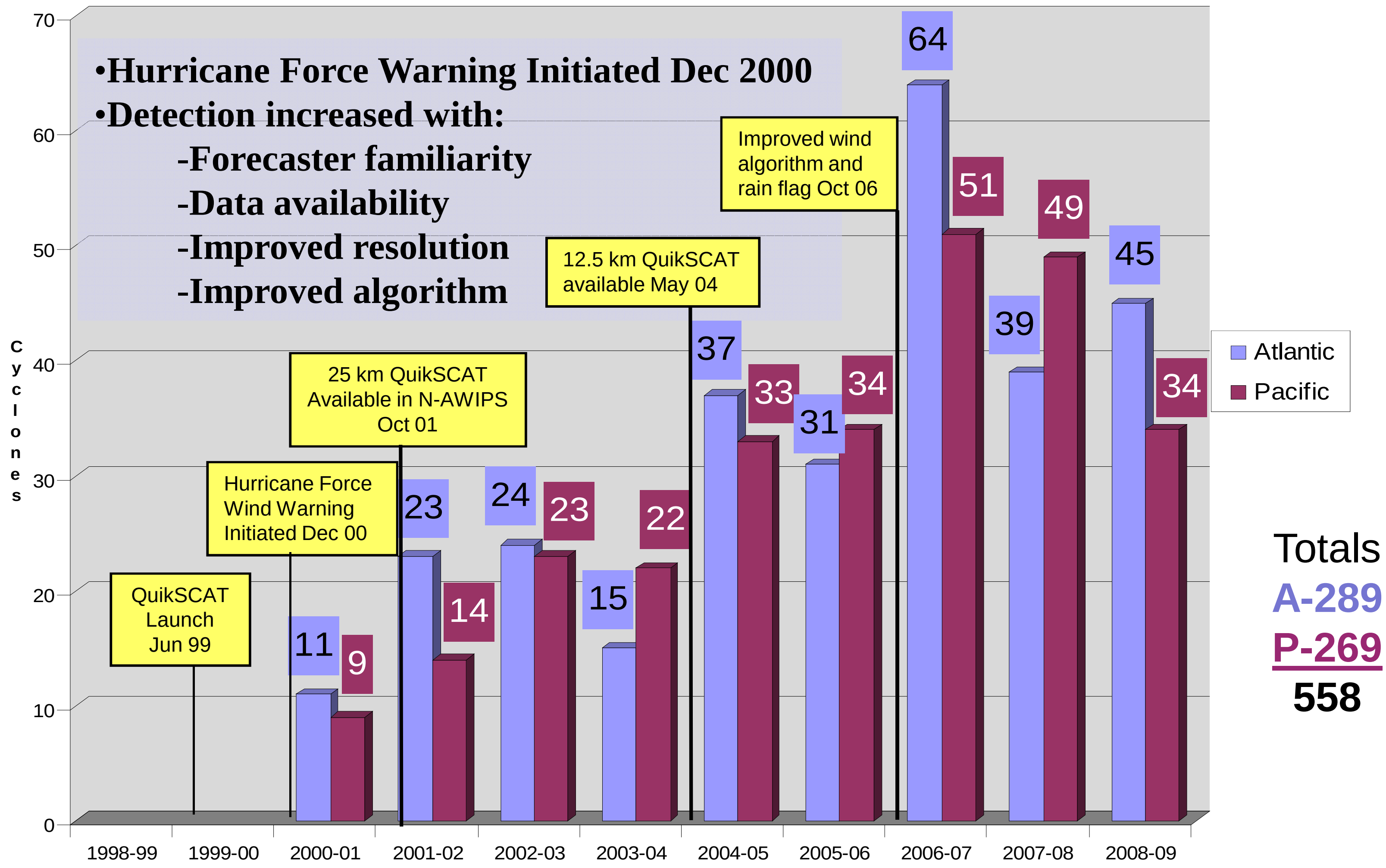


QuikSCAT era

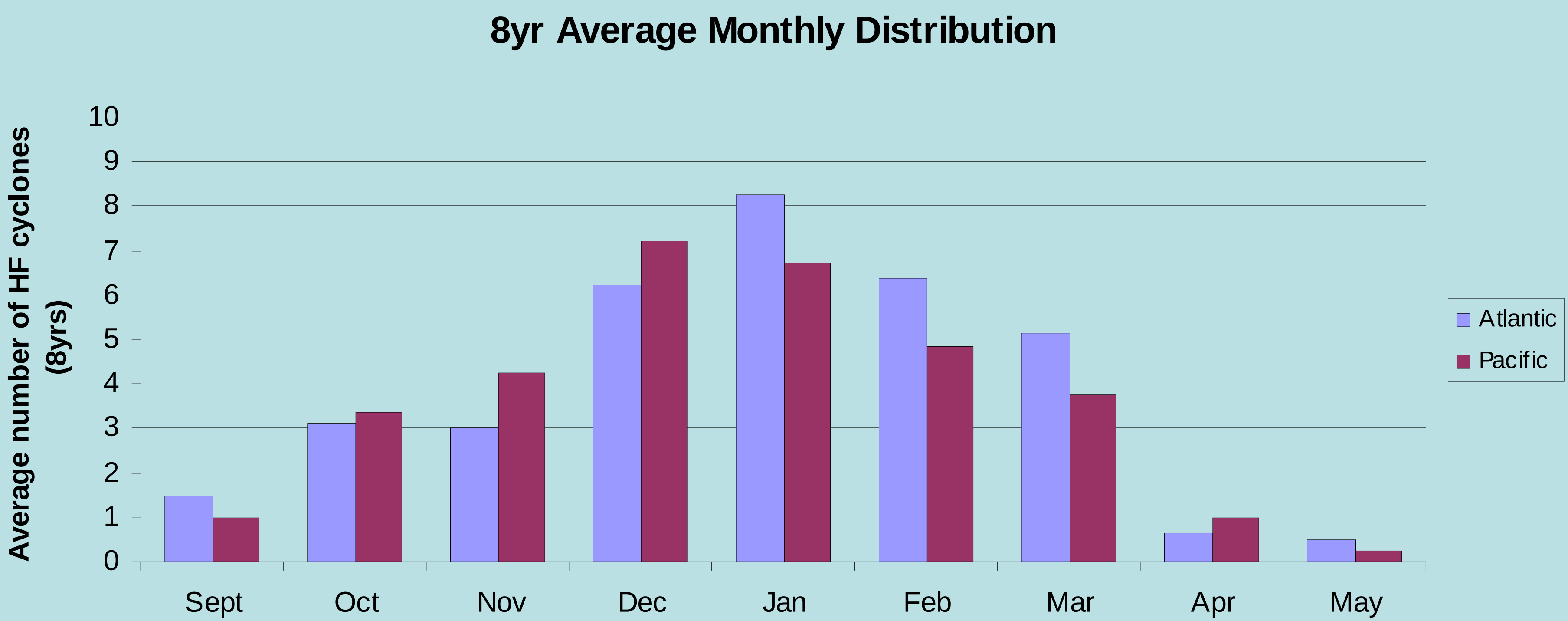


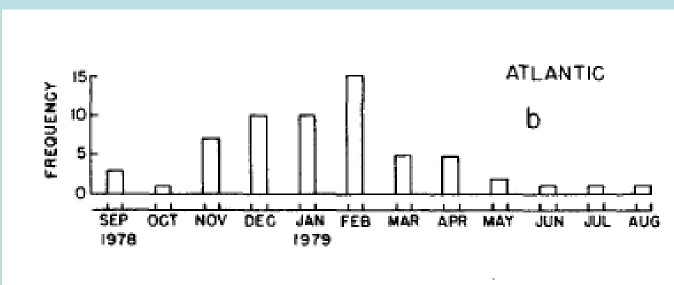
- Wide swath
  - reveals much of cyclone wind field
    - (complete coverage 2x's/day poleward of 49 degrees)
- Large retrievable wind speed range
  - (well into hurricane force)
- Limitations - resolution and rain
  - not as significant in extra-tropical cyclones as opposed to tropical cyclones
  - 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



Monthly Distribution 2001-2009





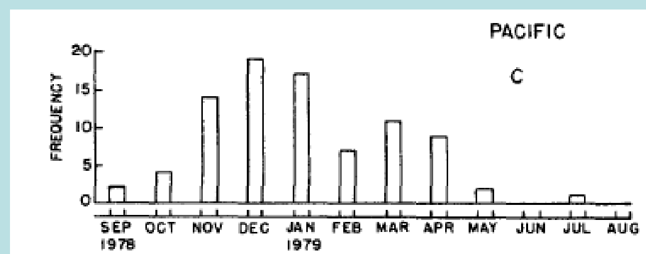
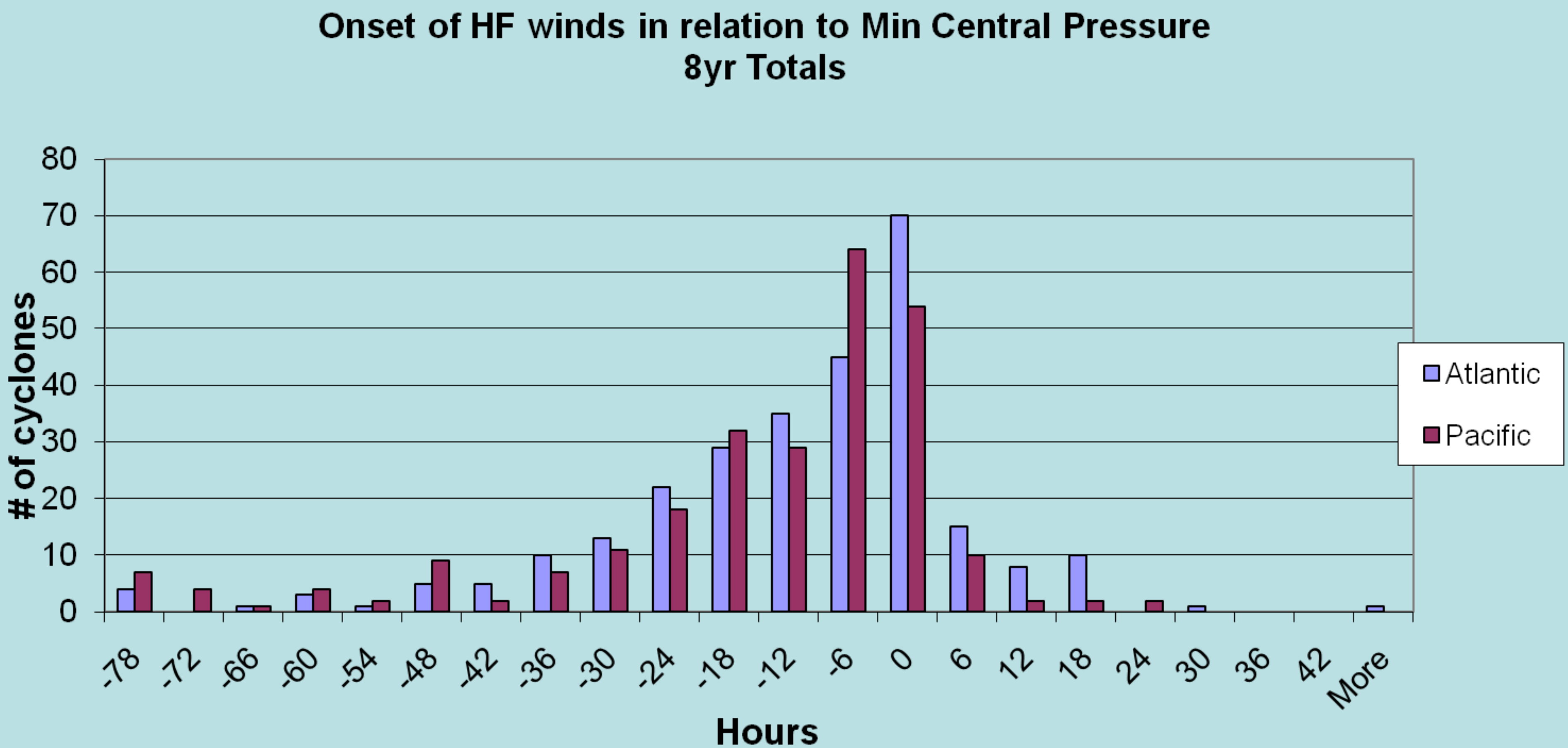
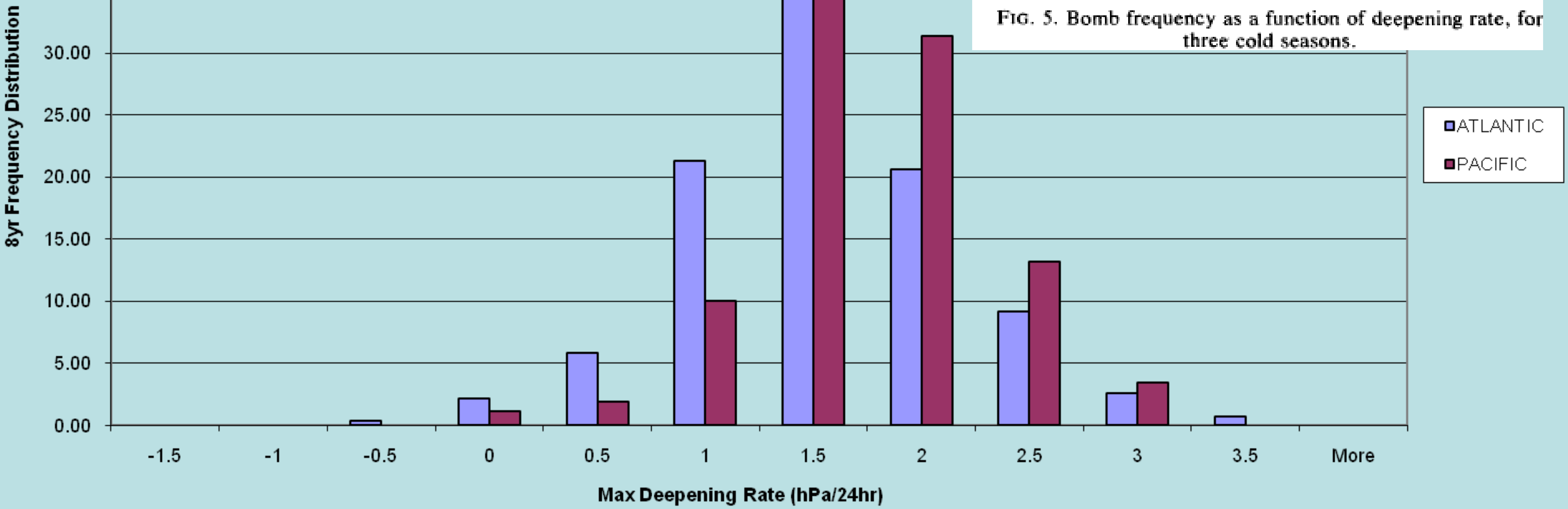


FIG. 9. Monthly bomb frequencies for 1978–79 season.

Onset of HF Winds 2001-2009



Frequency of Maximum Deepening Rate 2001-2009



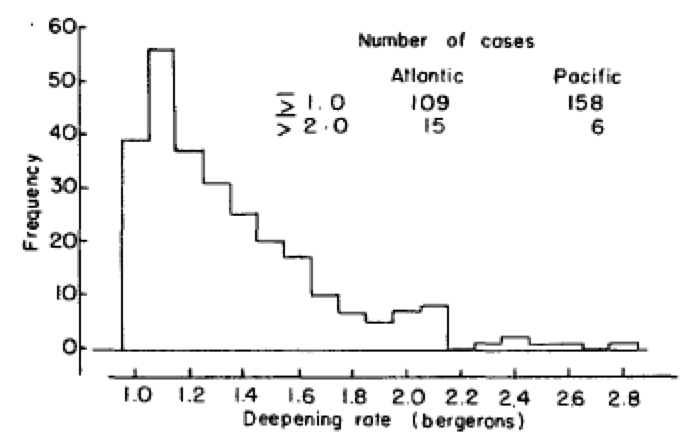
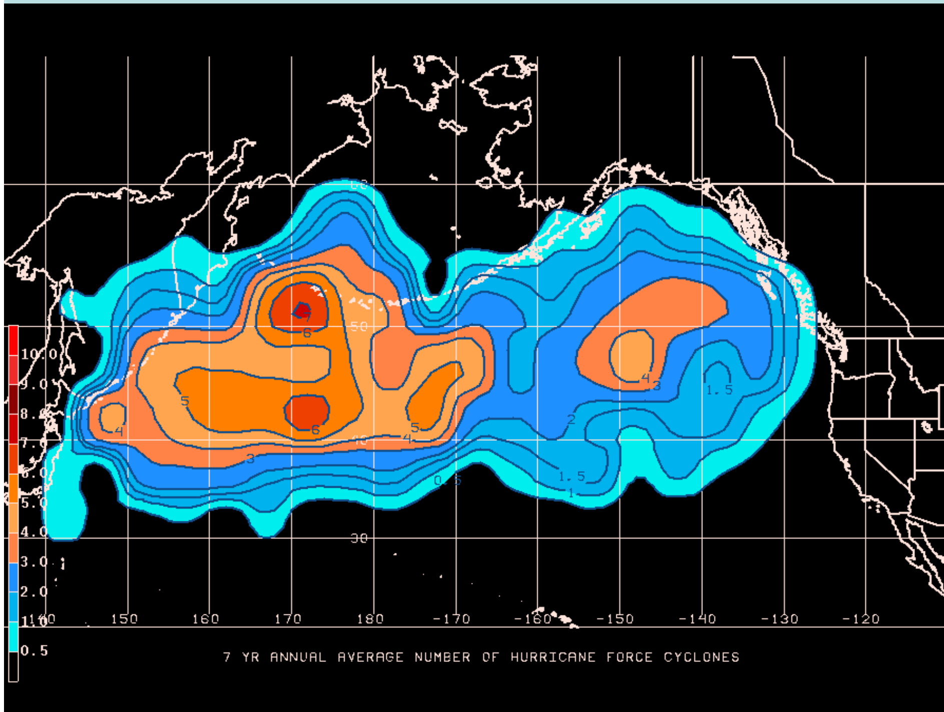
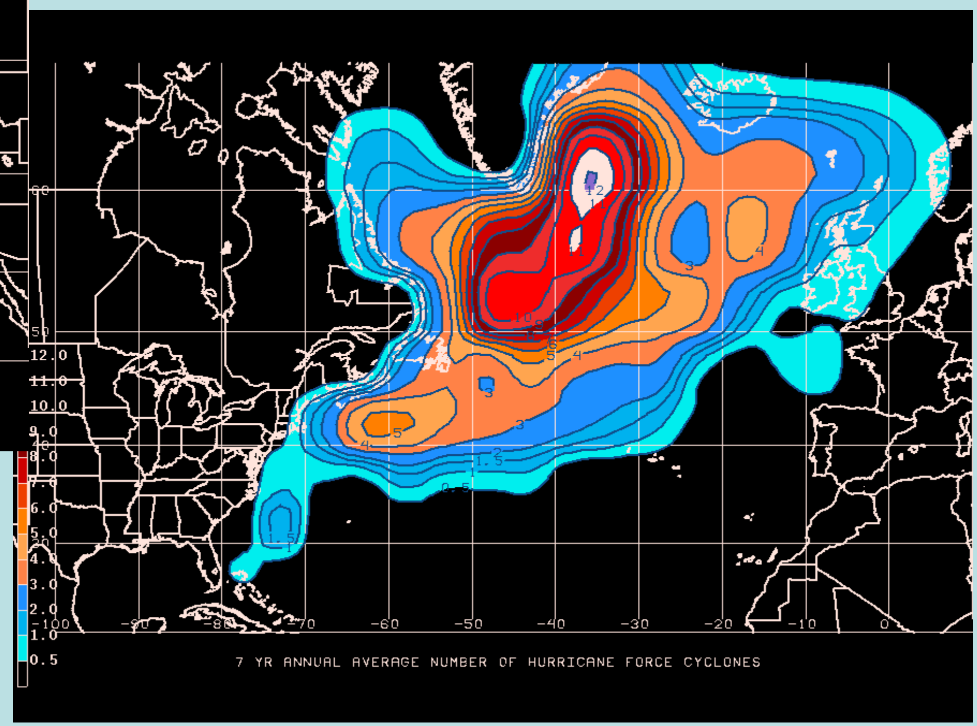
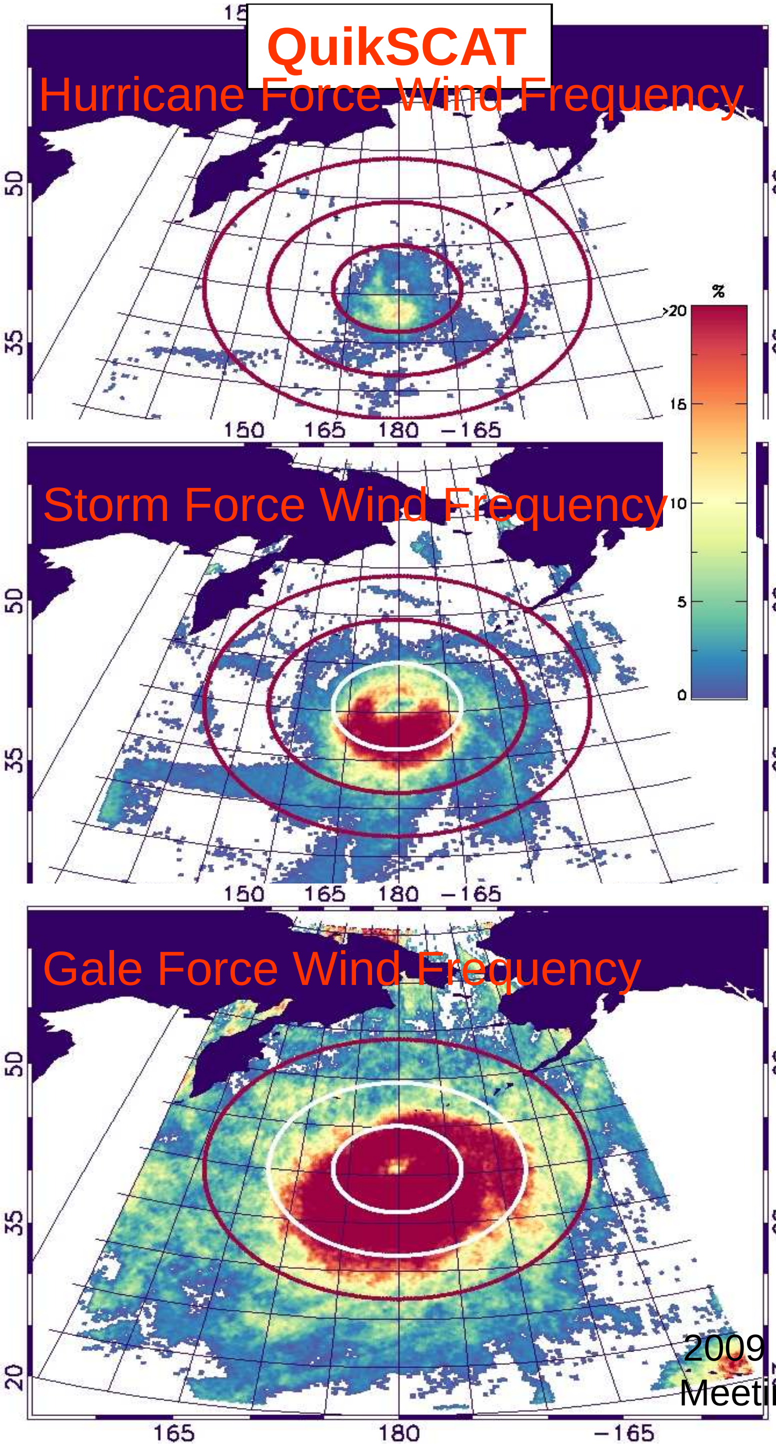


FIG. 5. Bomb frequency as a function of deepening rate, for three cold seasons.

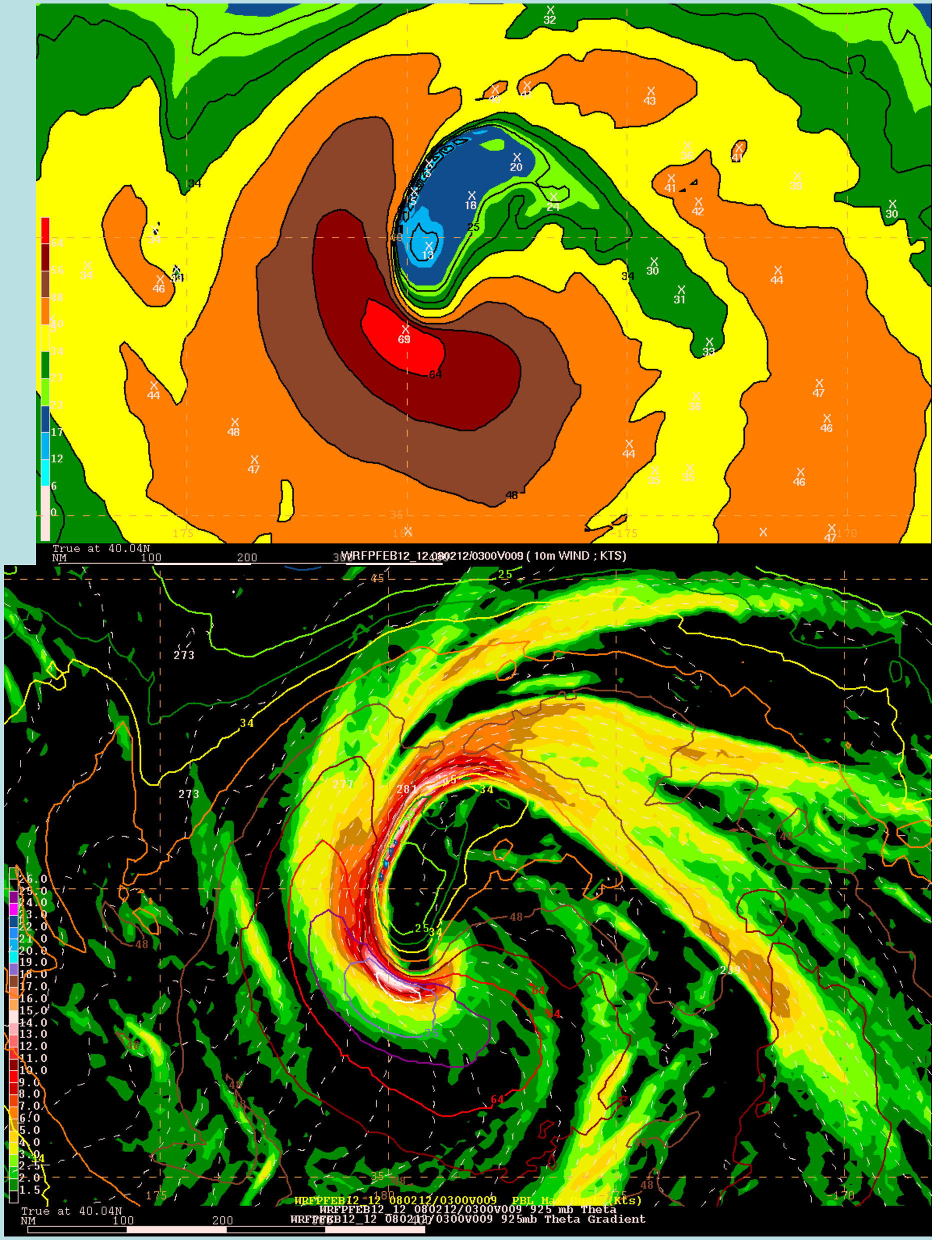
Geographic Distribution 2001-2008





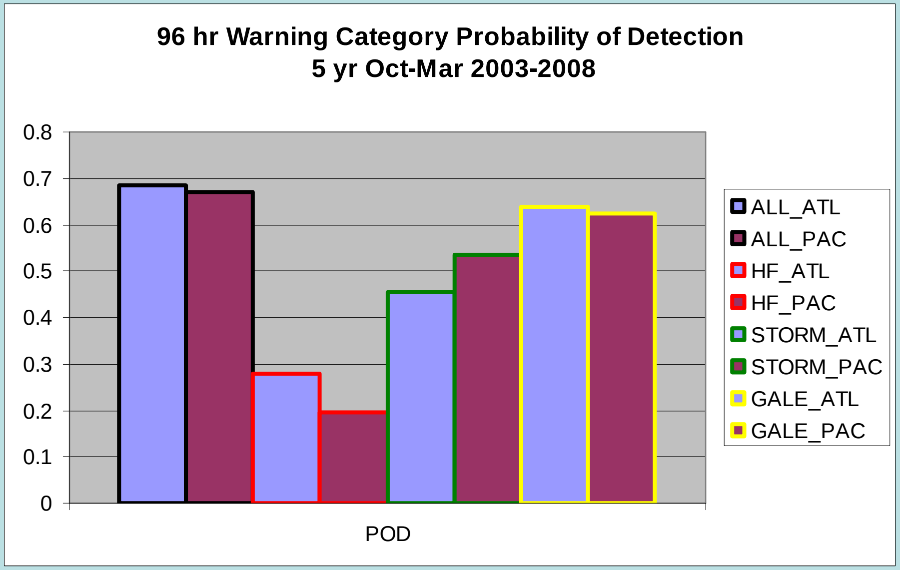


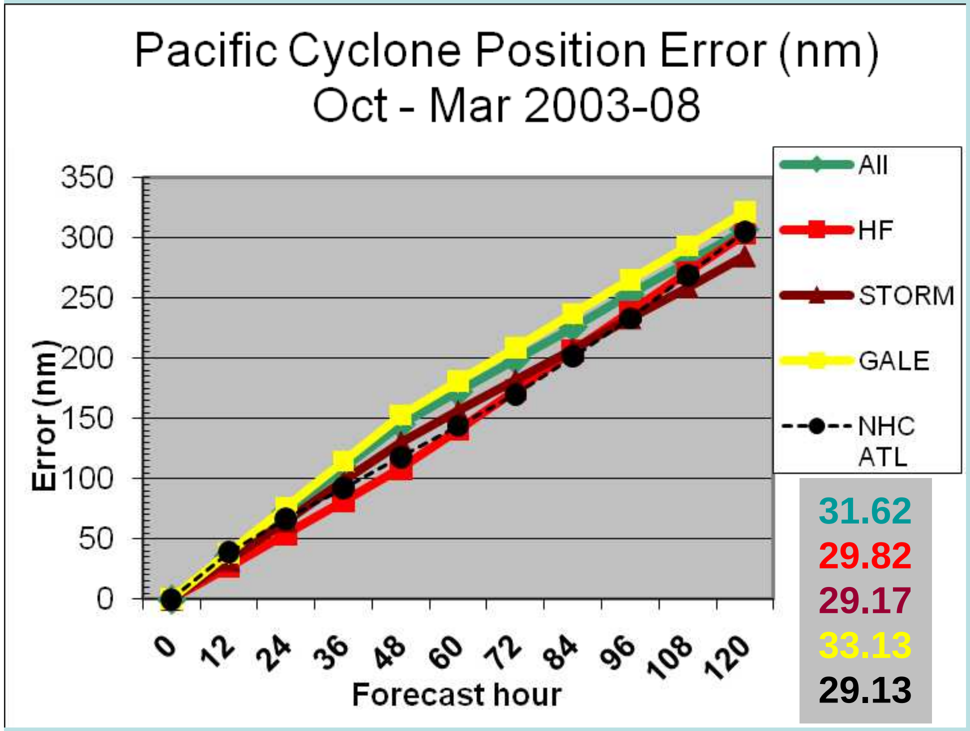
WRF Simulation Pacific Feb 2008 cyclone

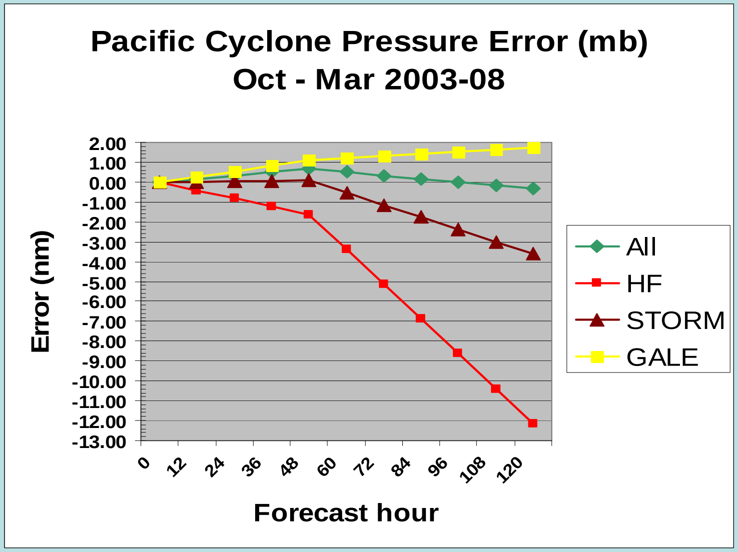


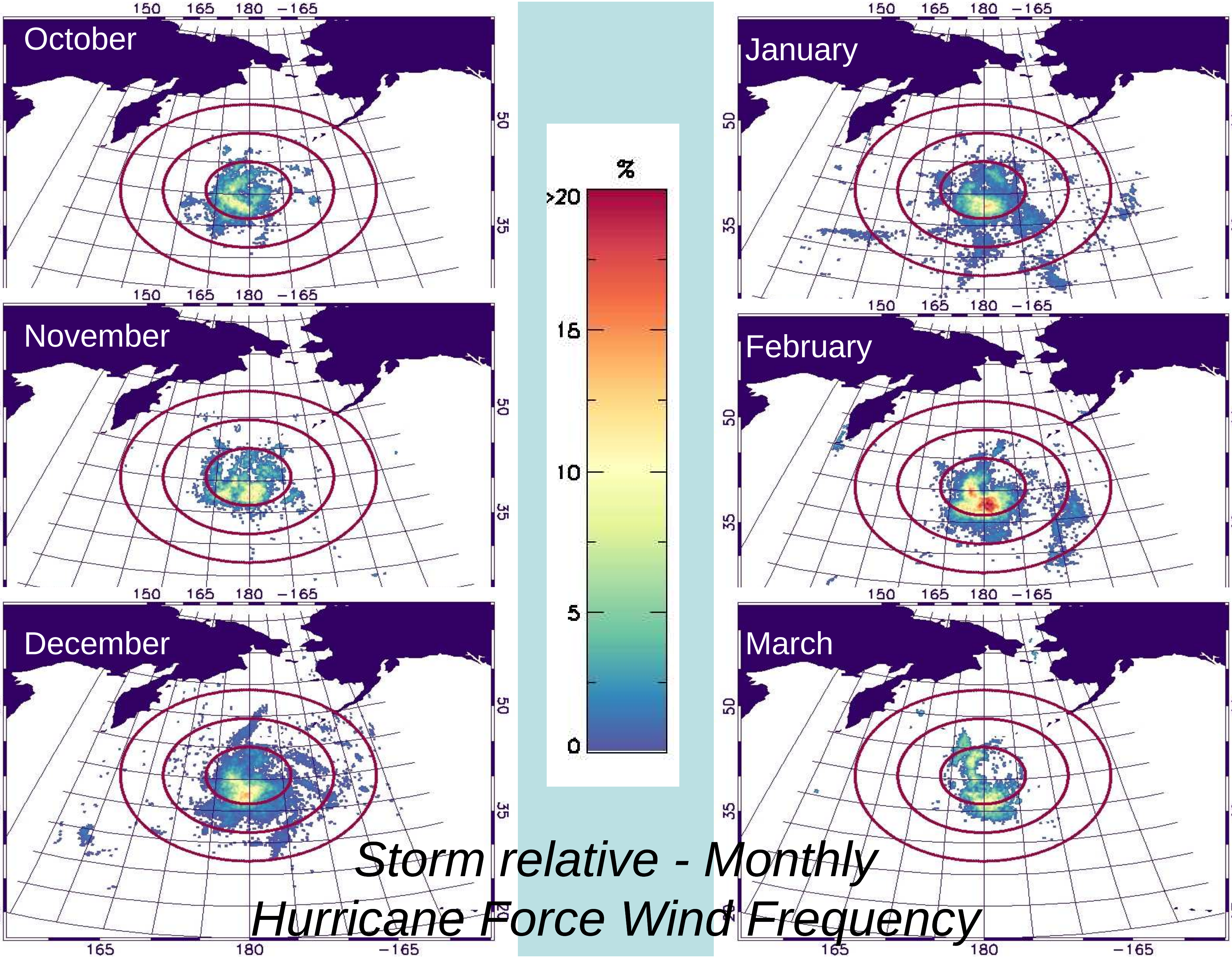
Forecast skill

- 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

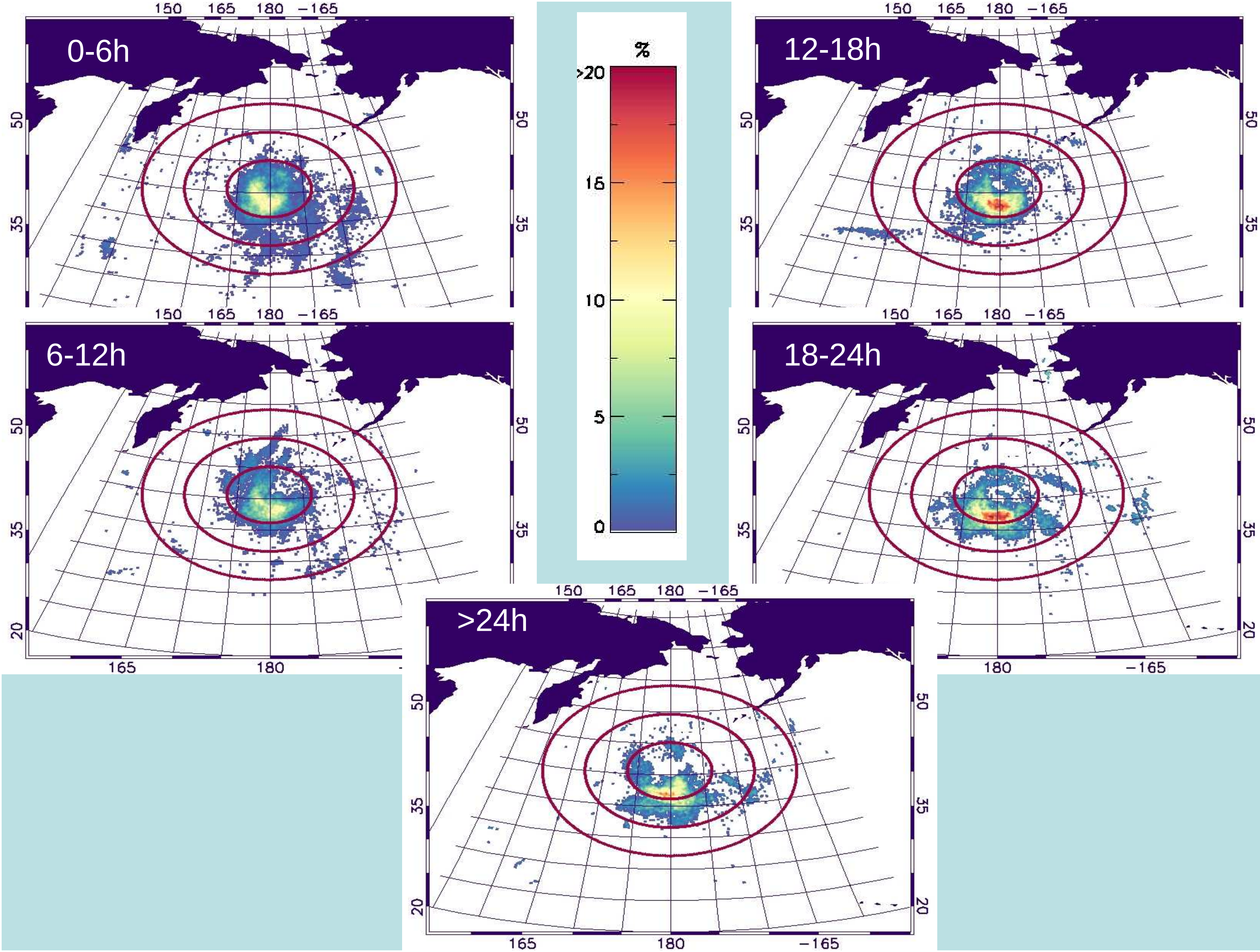






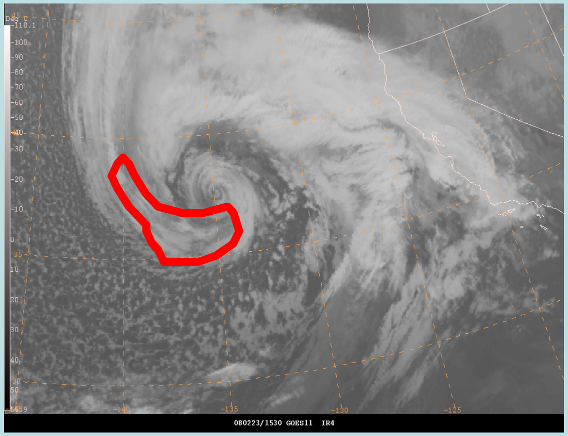


Storm relative - Monthly
Hurricane Force Wind Frequency


0-6h
6-12h
12-18h
18-24h
>24h
%
>20
15
10
5
0
150
165
180
−165
50
35
20

Hurricane Force Extra-tropical Cyclones

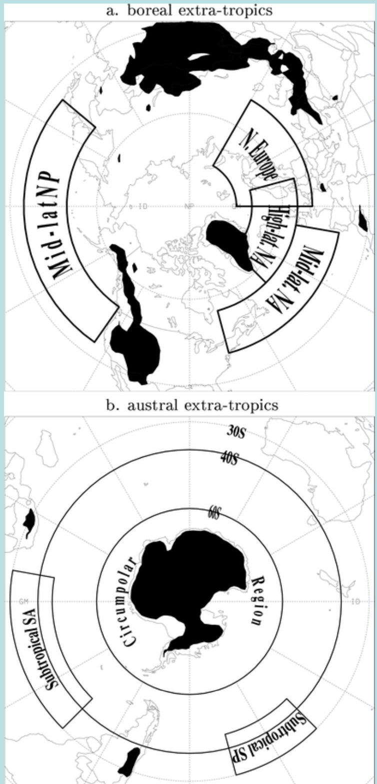
Gaining a grasp on behavior

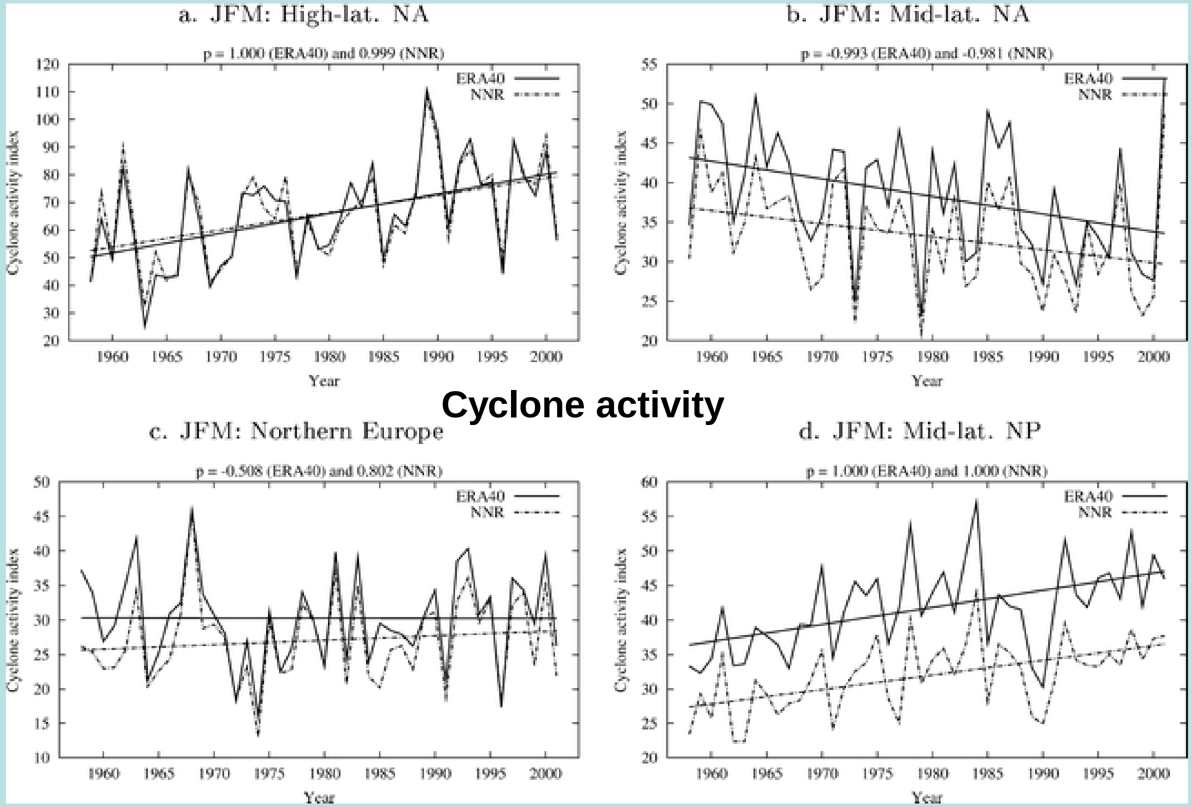


- Geographic distribution
- Monthly frequency
- Wind field distribution
- HF winds onset during rapid intensification
- Thermal structures required
- Quantified short-term predictability

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.

Climatology and Changes of Extratropical Cyclone Activity: Comparison of ERA-40 with NCEP–NCAR Reanalysis for 1958–2001
Xiaolan L. Wang, Val R. Swail, and Francis W. Zwiers

Contribution of ocean cyclone wind forcing to ocean circulation

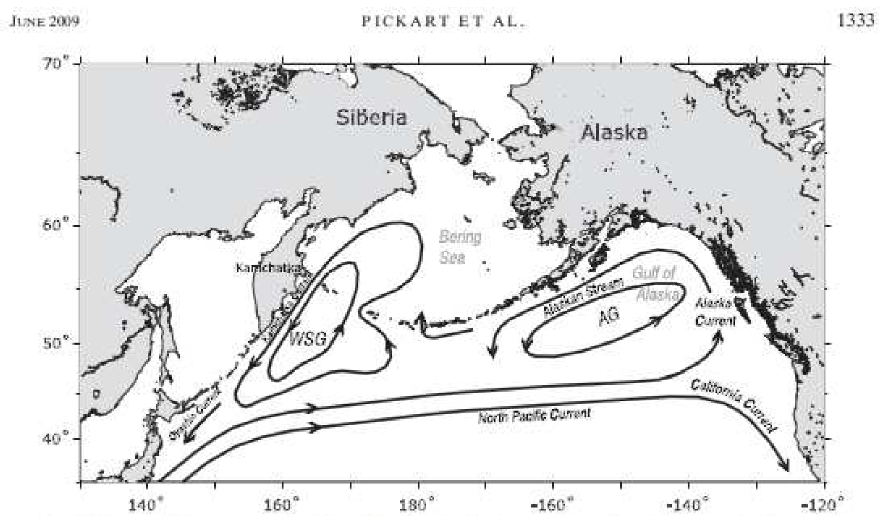


FIG. 13. Schematic of the upper-layer circulation of the North Pacific Ocean. AG stands for Alaska gyre and WSG stands for western subarctic gyre.

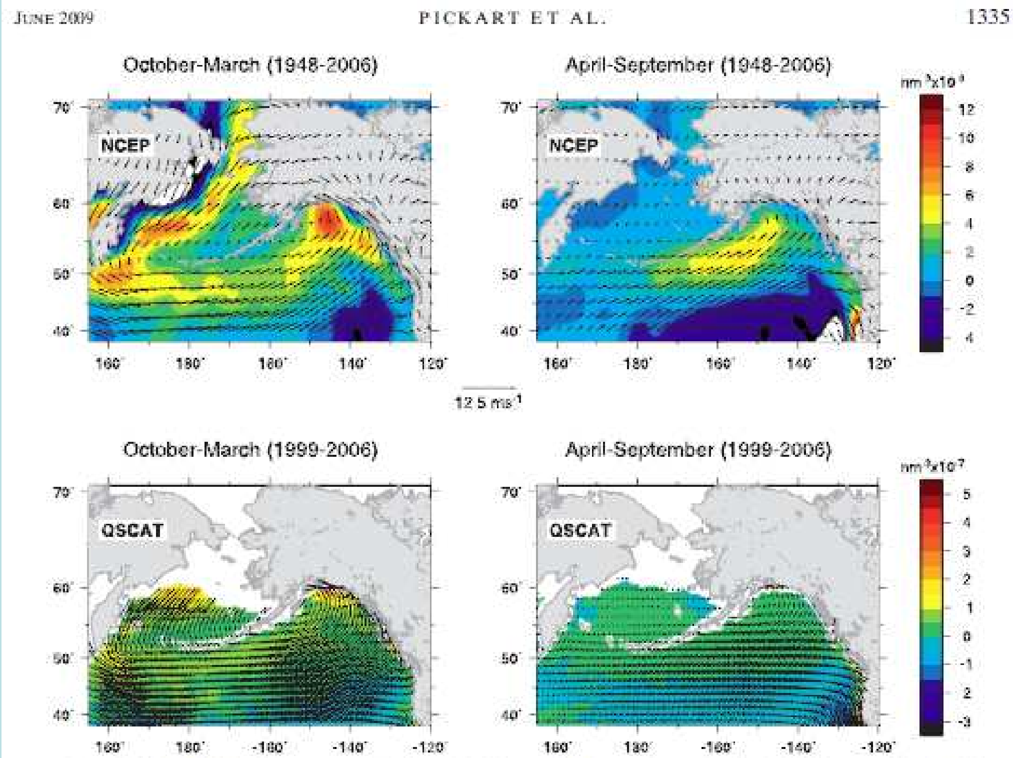
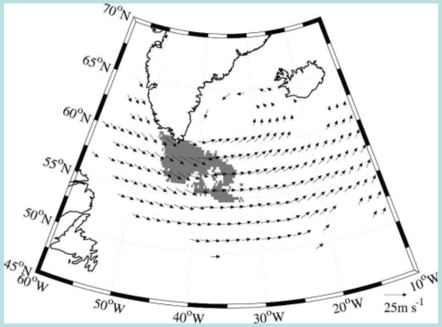


FIG. 15. Climatological wind stress curl (color) and wind vectors for the two 6-month periods (left) October–March and (right) April–September. The top row uses NCEP data for the period 1948–2006 (10-m winds), and the bottom row uses QuikSCAT data for the period 1999–2006 (surface winds, subsampled every fifth point). Note the different color scale used for the QuikSCAT-derived curl.

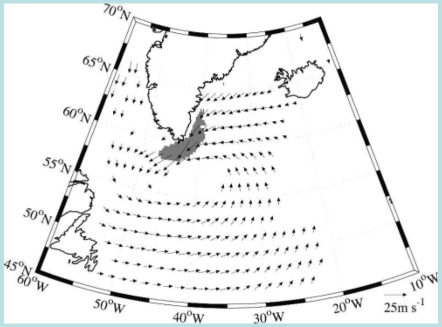
Pickart et al. 2009

…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.

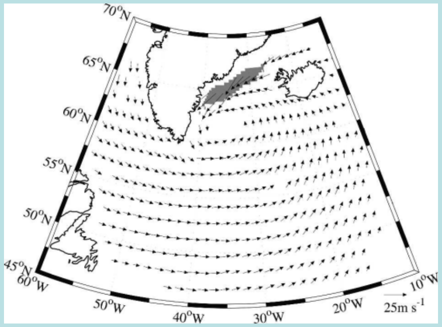
Contribution of ocean cyclone wind forcing to ocean circulation



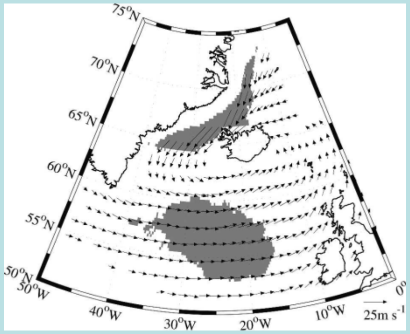
Tip jet



Reverse tip jet



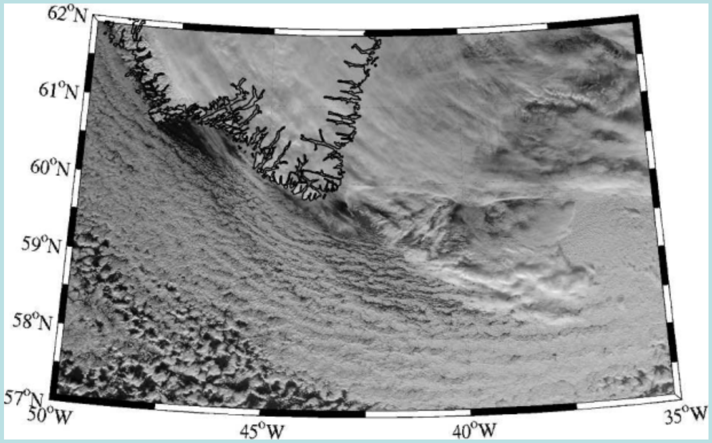
Barrier jet

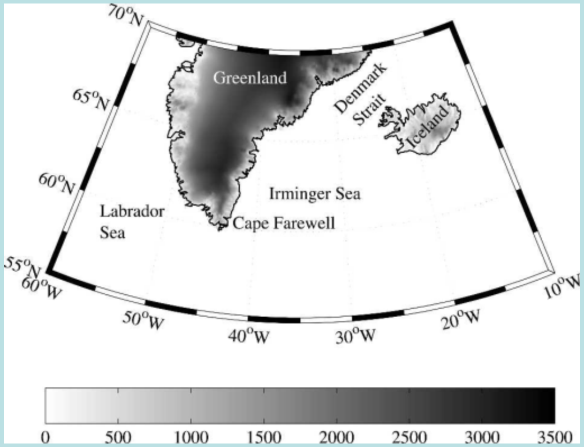


Denmark Strait barrier jet

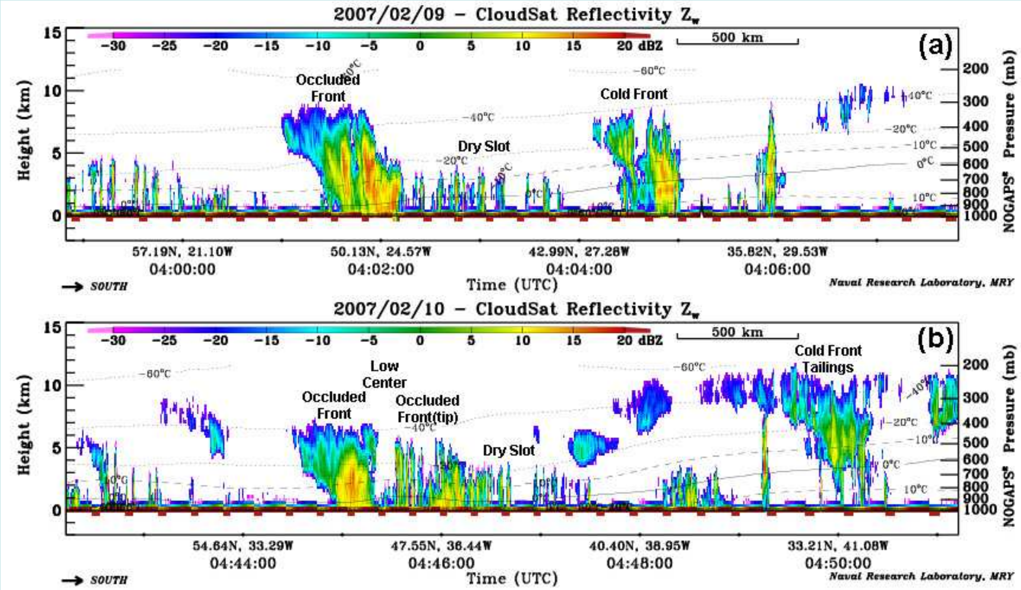
Moore and Renfrew, 2005

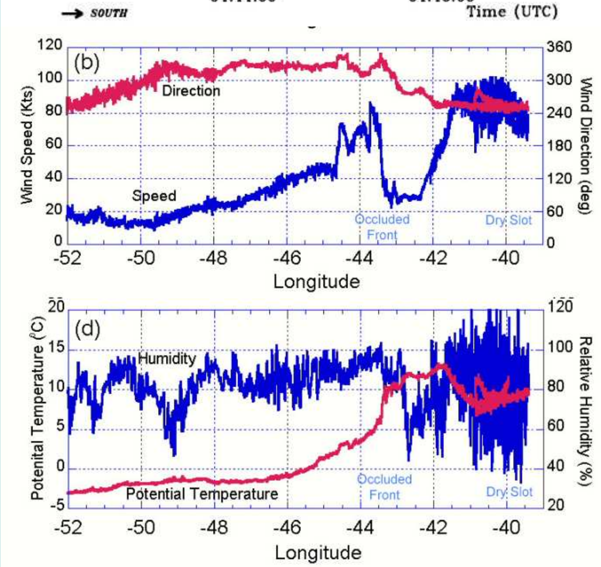
Deep ocean convection occurs in both the Labrador and Irminger Seas, with high wind speeds being crucial for the large air–sea heat and moisture exchanges that densify the surface waters and drive convection (Lab Sea Group 1998; Bacon et al. 2003; Pickart et al. 2003a,b).

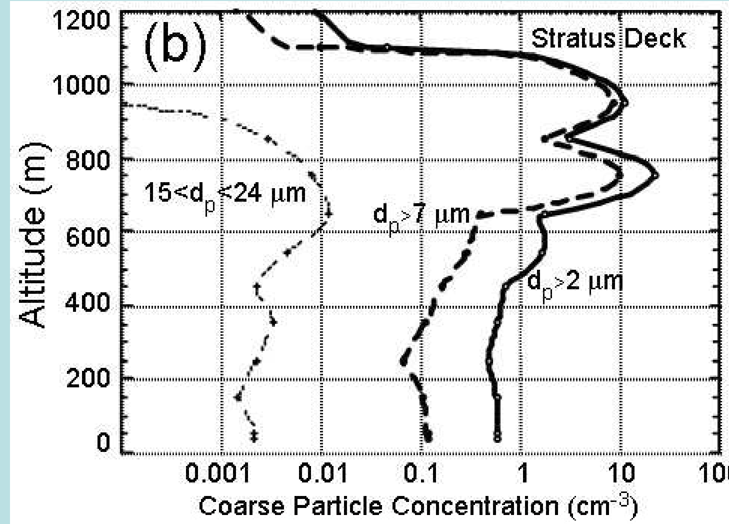




Extreme winds and salt spray





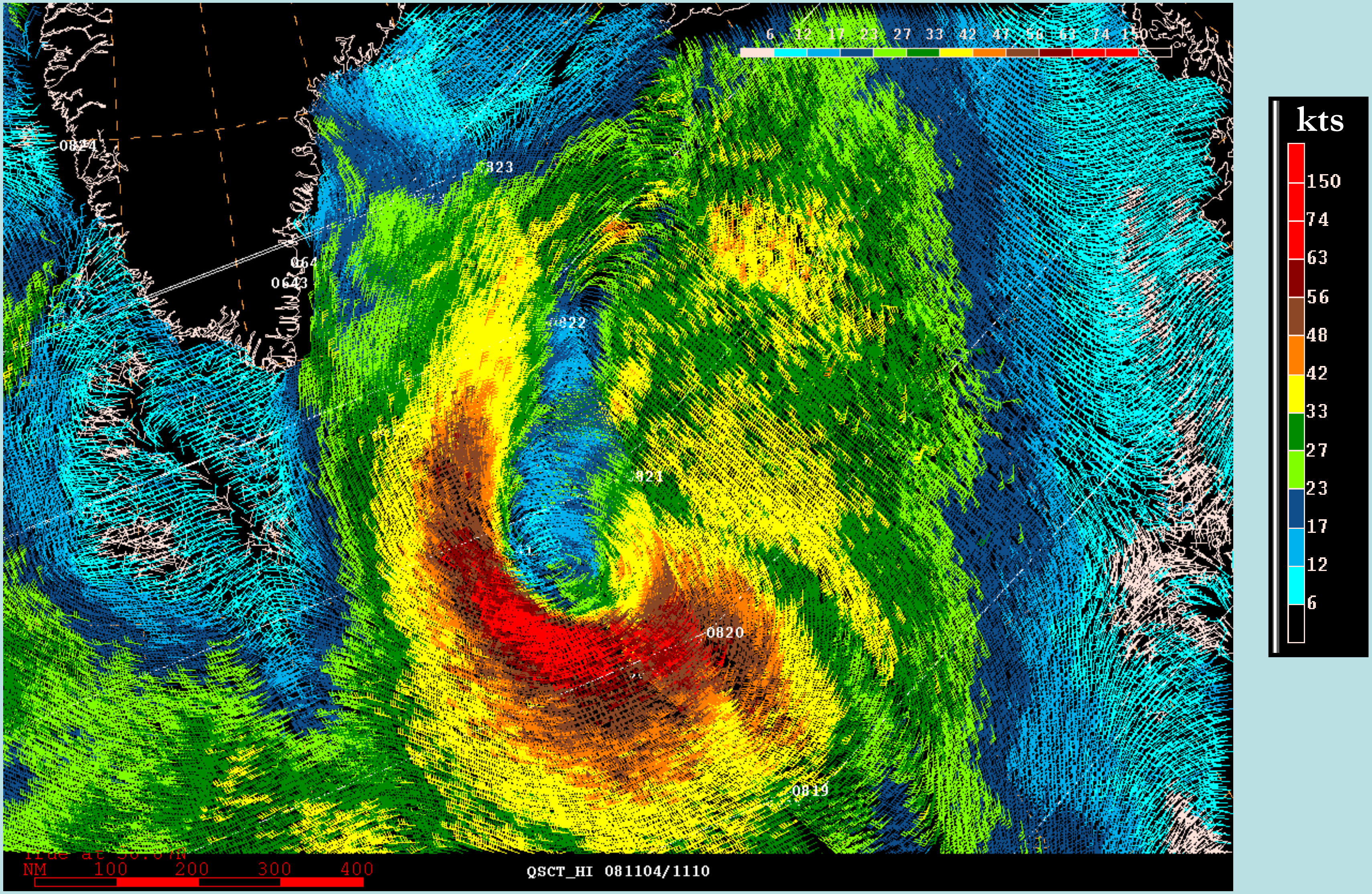


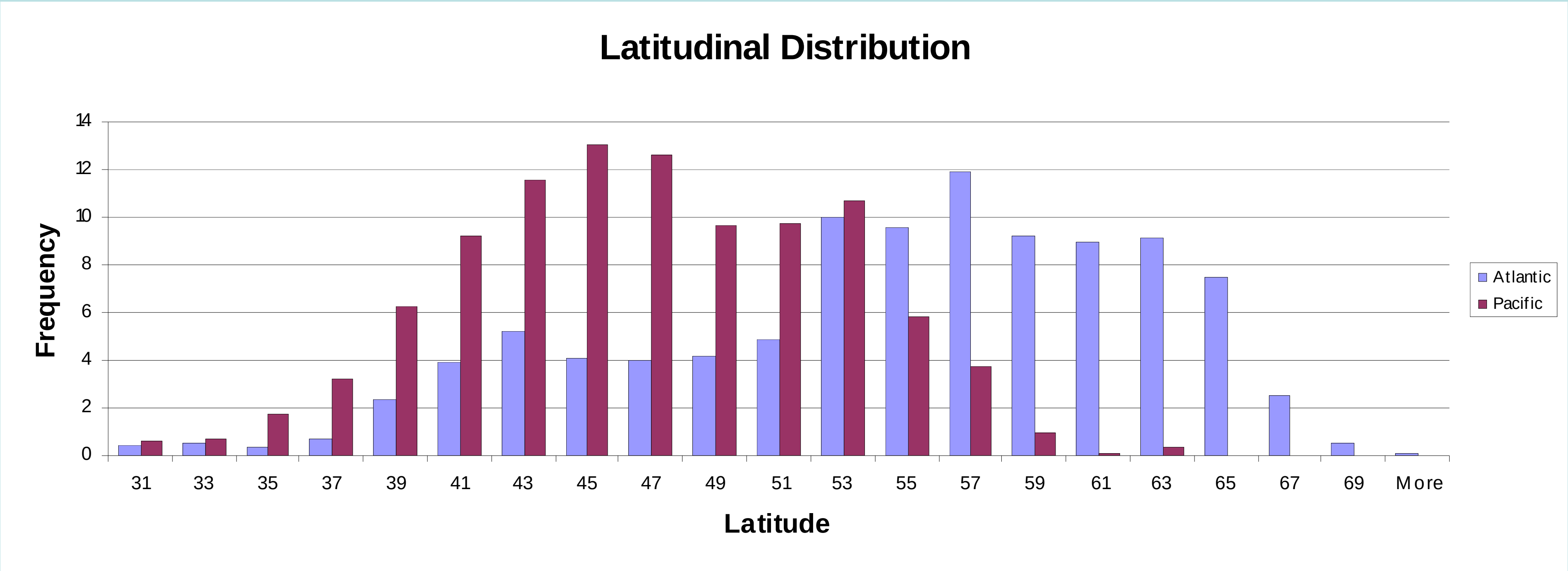
Reid et al., 2007 (NRL Report)

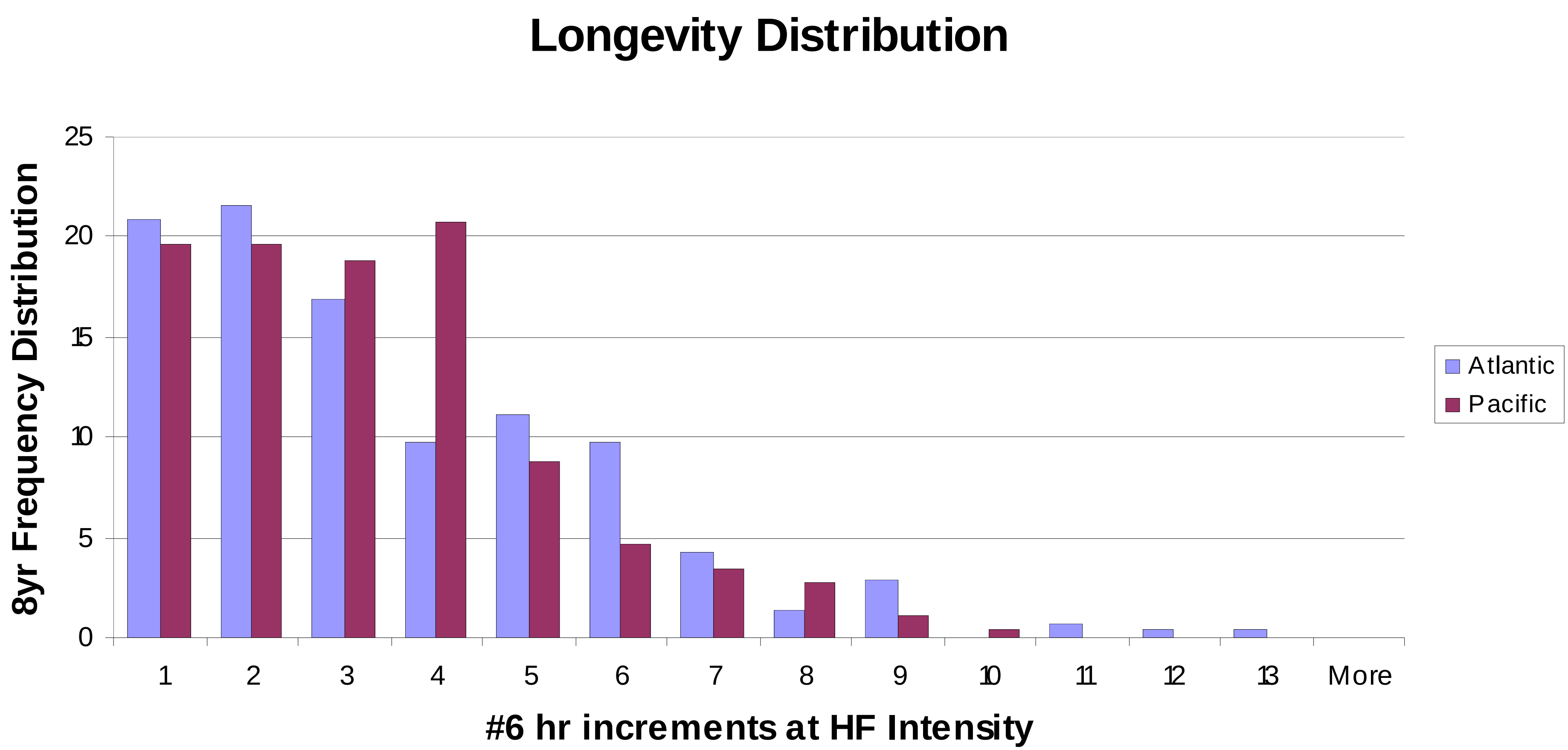
- High winds, long fetch, in non-precipitating conditions result in high concentrations of sea salt particles
- Giant mode salt spray particles in worst conditions probably to ~1.5 km

"extremely high sea salt particle concentrations are a previously unconsidered phenomenon in the scientific community"

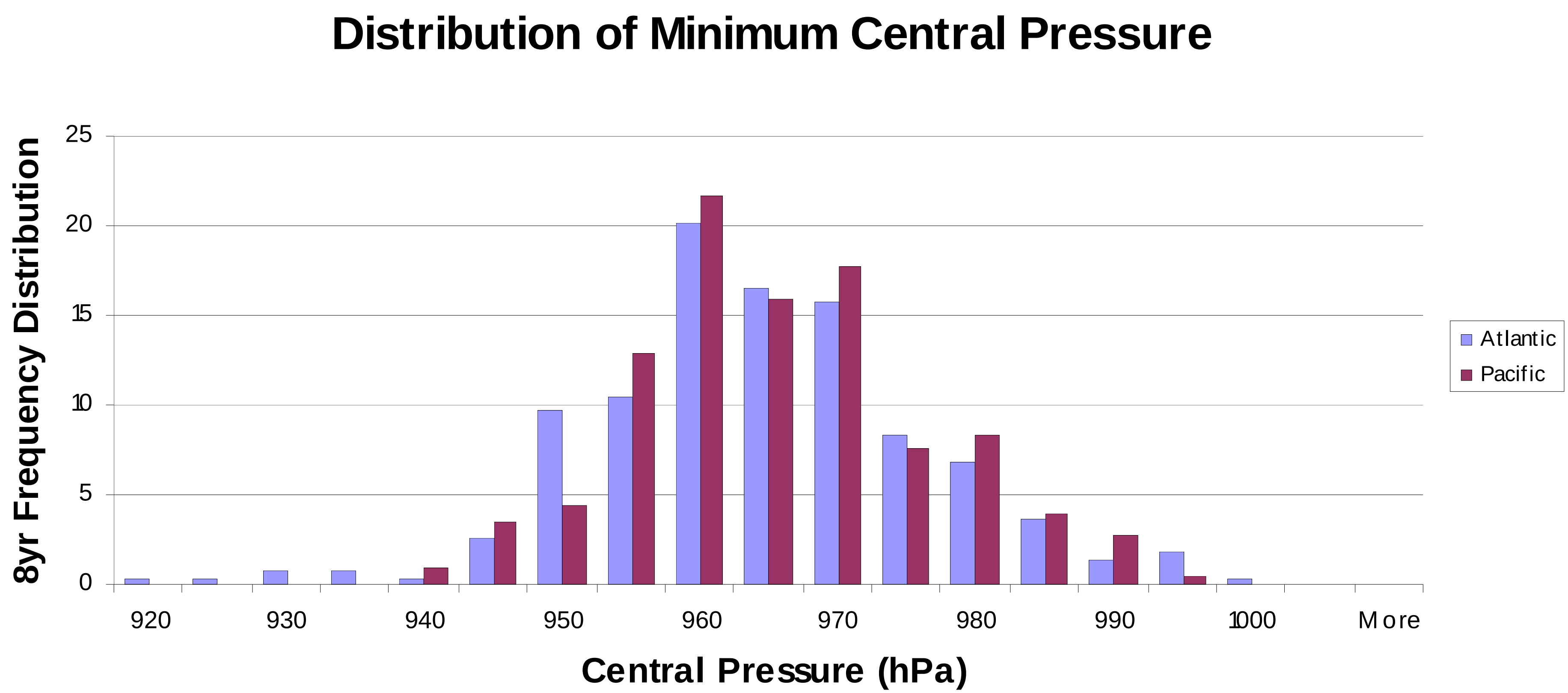
Summary

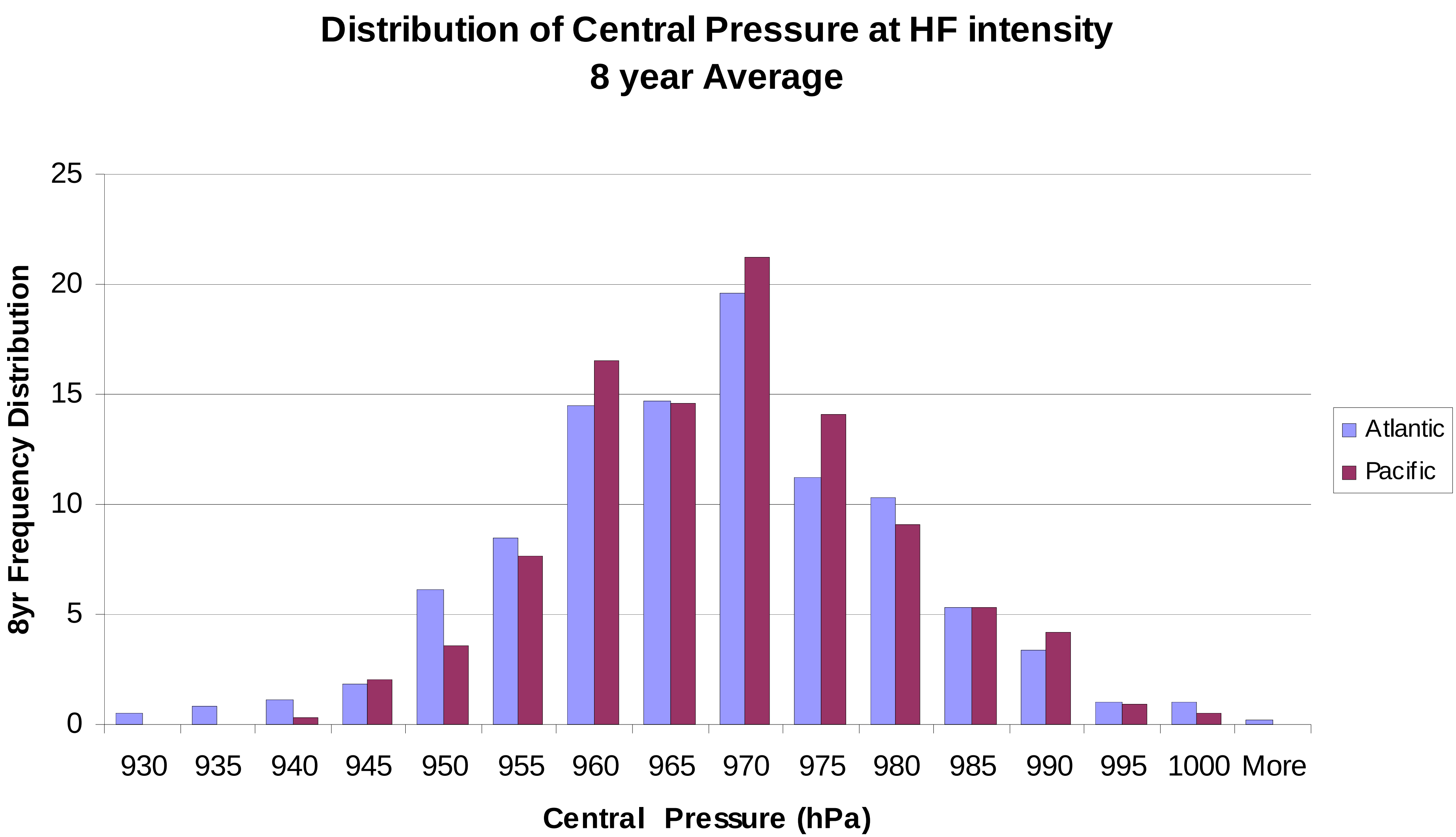

kts
150
74
63
56
48
42
33
27
23
17
12
6
0824
0823
0643
0822
0820
0819
NM 100 200 300 400
QSCT_HI 081104/1110

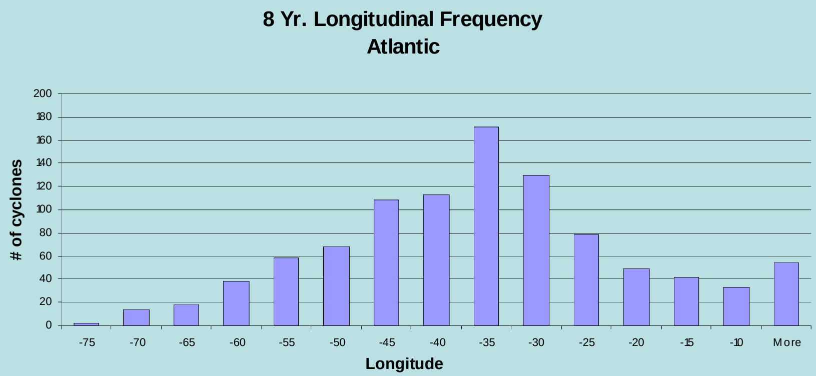

Latitudinal Distribution
Frequency
14
12
10
8
6
4
2
0
31
33
35
37
39
41
43
45
47
49
51
53
55
57
59
61
63
65
67
69
More
Latitude
Atlantic
Pacific

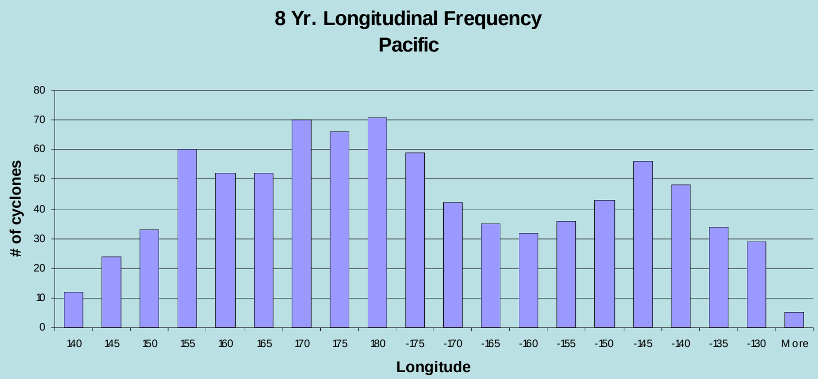


Longevity Distribution
8yr Frequency Distribution
#6 hr increments at HF Intensity
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
More
Atlantic
Pacific


Distribution of Minimum Central Pressure
8yr Frequency Distribution
25
20
15
10
5
0
920
930
940
950
960
970
980
990
1000
More
Central Pressure (hPa)
Atlantic
Pacific


Distribution of Central Pressure at HF intensity
8 year Average
8yr Frequency Distribution
0
5
10
15
20
25
930
935
940
945
950
955
960
965
970
975
980
985
990
995
1000
More
Central Pressure (hPa)
Atlantic
Pacific


8 Yr. Longitudinal Frequency
Atlantic
# of cyclones
Longitude
0
20
40
60
80
100
120
140
160
180
200
-75
-70
-65
-60
-55
-50
-45
-40
-35
-30
-25
-20
-15
-10
More


8 Yr. Longitudinal Frequency
Pacific
# of cyclones
Longitude
0
10
20
30
40
50
60
70
80
140
145
150
155
160
165
170
175
180
-175
-170
-165
-160
-155
-150
-145
-140
-135
-130
More

Cross-sections

theta-e (dashed), theta-e gradient (filled colored contours), isotachs (solid lines, knots)