Extratropical Cyclone Clouds: Impact on Cyclone Strength and Climate

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Topics

Introduction and Motives
- What constitutes a cyclone? What is its role?
- Research Objectives
- The MCMS Dataset

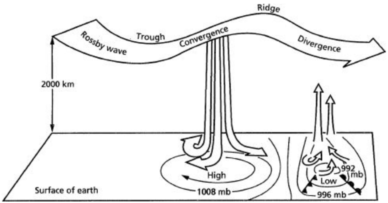
Analysis of Cyclone Tracking
- Cyclone Center Properties

Classification and statistics of cyclones
- Distributions and classification
- Seasonal Variability of Classification
- Interannual trends of classification

Conclusions and acknowledgements

What constitutes an extratropical cyclone?

A few introductory remarks.

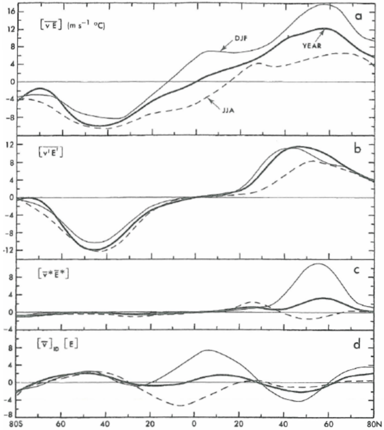


Rossby wave cartoons.

- ECs are associated with atmospheric Rossby waves.
- Solutions to equations of motion for rotating stratified fluid.
- Upper level disturbance leads to surface motions.
- "Cyclone" refers to low pressure half of these motions collectively, and is somewhat nebulous.

What role/purpose does the extratropical cyclone serve?

Equilibrate the polar temperature gradient.

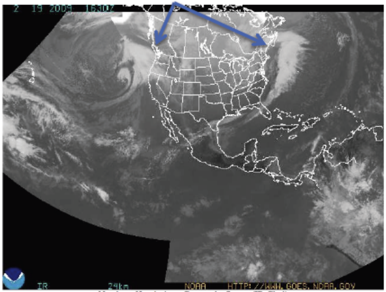


Left: Northward transport of energy.

(a) total, (b) transient, (c) stationary, (d) mean meridional overturning (Peixoto and Oort 1992).

Below: Rossby wave induced activity.

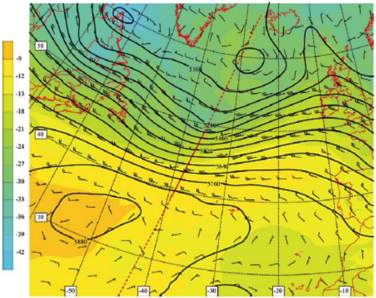
Transient waves



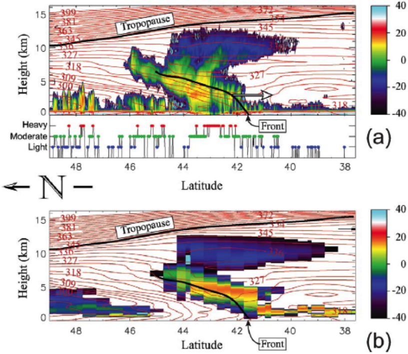
Northern Hemisphere Composite Sector (IR Ch 4)

What role/purpose does the extratropical cyclone serve?

Redistribute mass, specifically moisture.



Below: (a) CloudSat observed and (b) ECMWF simulated radar reflectivity.



Above: Contours: 500 hPa geopotential height; shading: temperature; barbs: wind velocity; red line: frontal transect. (Posselt et al., 2008).

Research Objectives

Direction and scope of this work; dissertation goals.

Understand what factors affect development and lead to spectrum of strength.

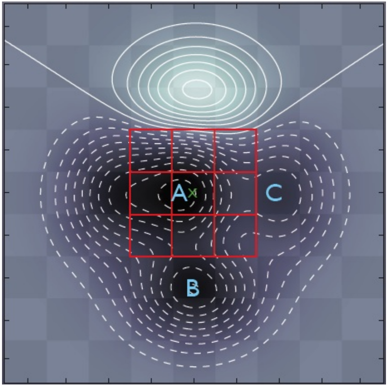
- Is there a observable pattern favoring rare strong storms opposed to frequent weak storms?
- Is one type of rare storm doing all the poleward transport work, or does the complement of more frequent cases do more/comparable work?

Determine role of cloud diabatic heating in storm evolution.

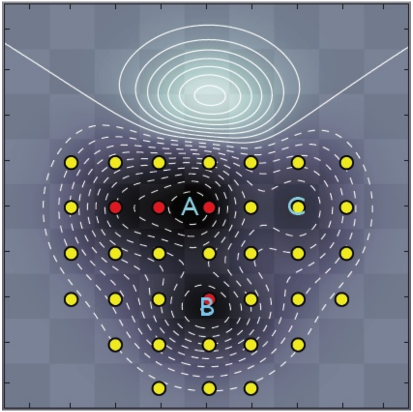
- Vertical heating profiles for cloud types associated with cyclones suggest dynamical impact (Haynes et al. 2011).
- Latent heating frequently considered, not cloud radiative heat.

MCMS Cyclone Tracking Algorithm

Modeling Analysis and Prediction (MAP) Climatology of Midlatitude Storminess



Below: Regions of storminess contained in outer closed SLP contour. Entangled lows identified (Bauer).

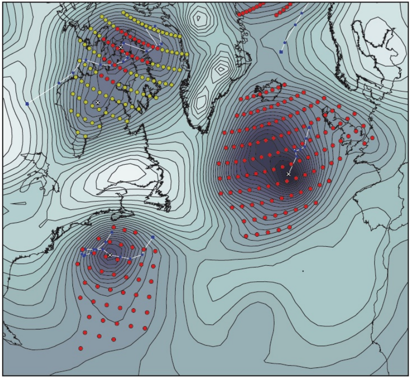


Above: For every grid, search adjacent grids for SLP minima. Identify centers by looking for closed SLP contours (Bauer).

MCMS Cyclone Tracking Algorithm

Modeling Analysis and Prediction (MAP) Climatology of Midlatitude Storminess

1979–2012 NCEP/NCAR 2

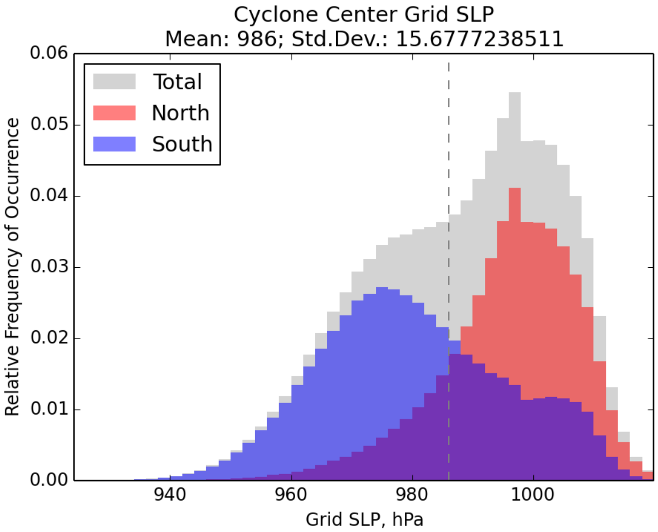


12:00 UTC 1991 Oct 30, Halloween Nor'easter at peak intensity (Bauer).

- Searches every grid at every time step, using a filter sequence to track identified systems between steps.
- Attributes grids to cyclone center, account for entangled lows.
- Distinguish stormy and non-stormy regions.
- Treatment for known SLP tracking problems, merging/splitting, etc.

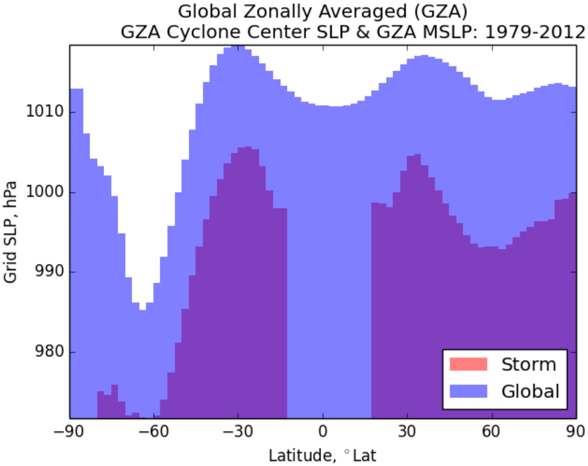
Cyclone Center Properties

Distributions of center grid SLP



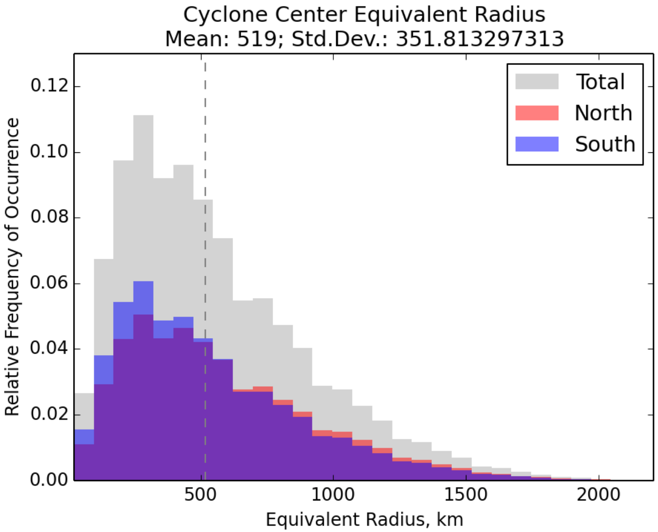
Cyclone Center Properties

Zonal Mean Cyclone Center SLP v. all SLP



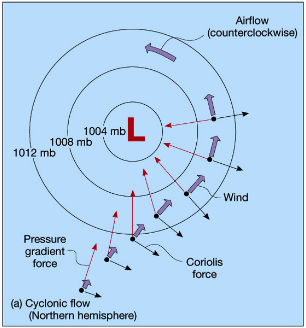
Cyclone Center Properties

Distributions of (area derived) equivalent radius



Cyclone Center Properties

First attempts to define some strength metric



Geostrophic Balance (GSB):

$$-fv \approx -\frac{1}{\rho}\frac{\partial p}{\partial x}$$

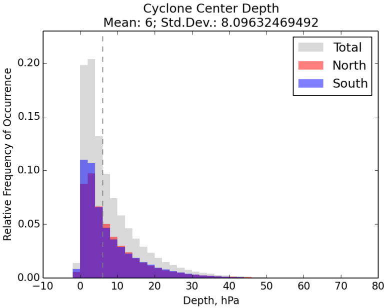
$$fu \approx -\frac{1}{\rho}\frac{\partial p}{\partial y}$$

$$|\mathbf{u_g}| = \frac{1}{\rho f}\nabla p$$

Coriolis parameter:
$f = 2\Omega \sin\phi$
Horizontal velocity:
u, v.

Cyclone Center Properties

First attempts to define some strength metric



Cyclone center depth calculated from SLP minima to largest surrounding closed SLP contour.

Let depth $\equiv \partial p$, and using GSB:

$$|\mathbf{u_g}| = \frac{1}{\rho f}\nabla p,$$

and approximate

$$\nabla = \frac{1}{\partial x_i} \approx \frac{1}{\partial r}.$$

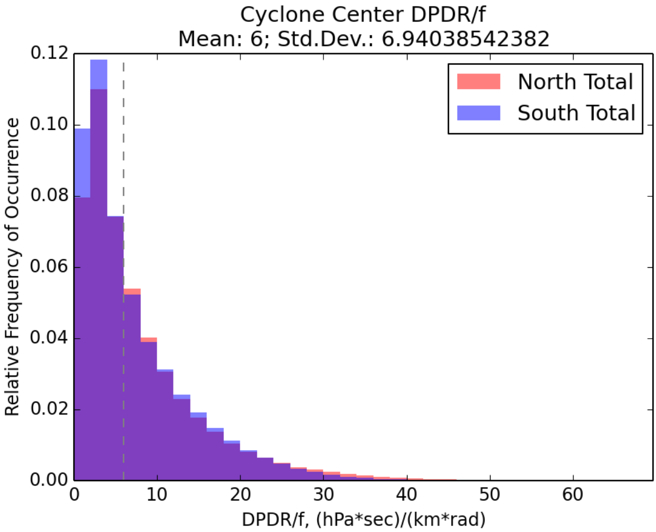
Removing mass dependency:

$$|\mathbf{u_g}| \approx \frac{1}{f}\frac{\partial p}{\partial r} = \frac{\partial p}{fR}.$$

Use as wind speed proxy.

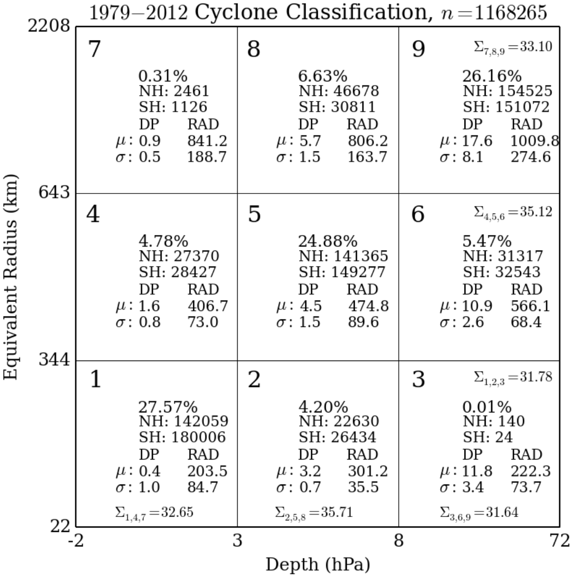
Cyclone Center Properties

Distributions of $\partial p/\partial r$ (NCEP/NCAR 2)



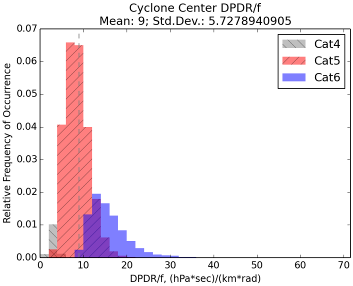
Classification and statistics of cyclone centers

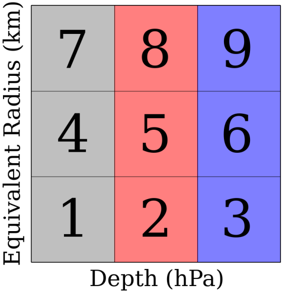
Percentile separation and classification



Distributions of Classification

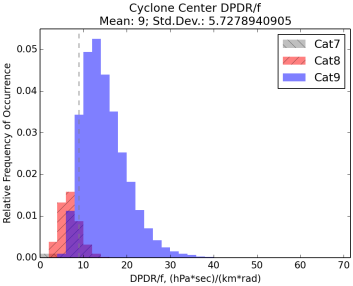
Center $\partial p / f \partial r$

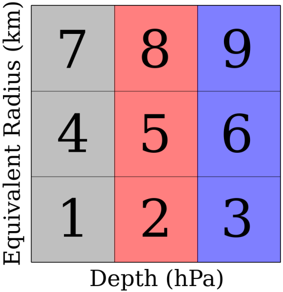




Distributions of Classification

Center $\partial p / f \partial r$





Distributions of Classification

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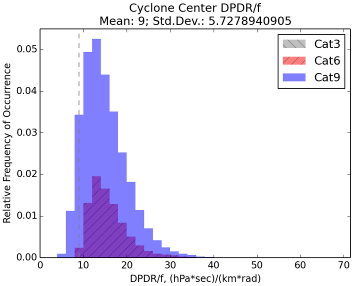
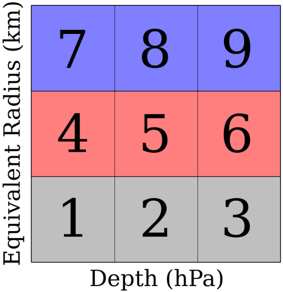
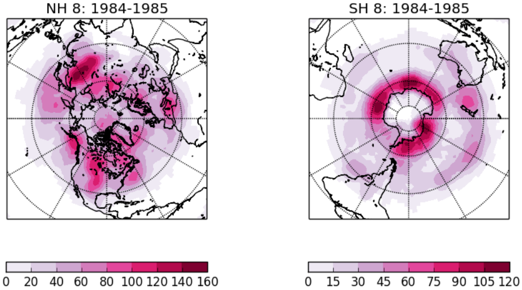




Locations of DP–RAD Groups 8 and 9

Climatological lows, storm tracks, and topography



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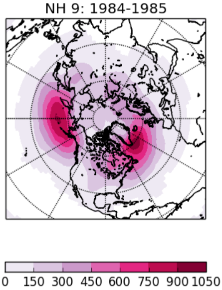
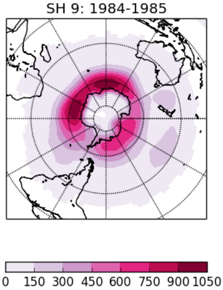
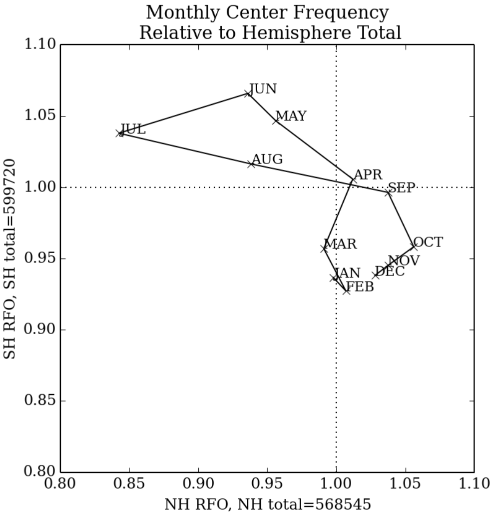




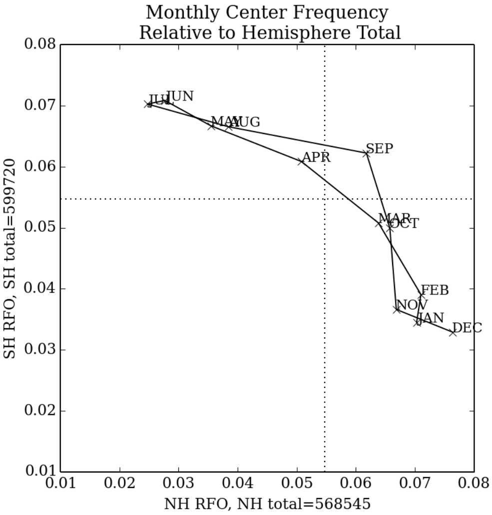
Monthly Variability

Without Classification, All Cyclones



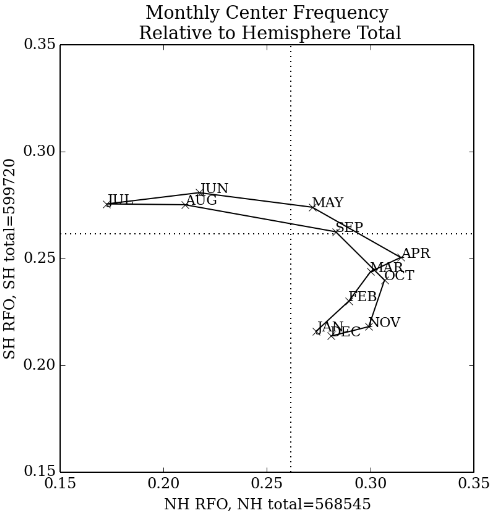
Monthly Variability

DP–RAD Group 6



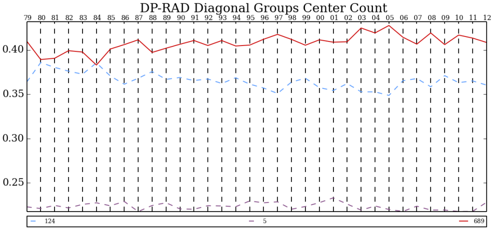
Monthly Variability

DP–RAD Group 9



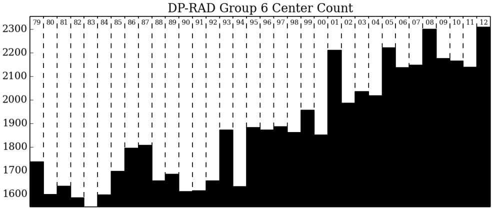
Interannual Trends of Classification

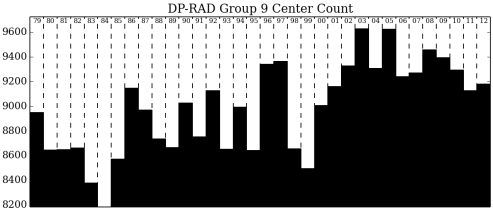
Combination of DP–RAD Groups 6, 8, and 9



Interannual Trends of Classification

DP–RAD Group 6





Conclusions and acknowledgements

- Compute cloud radiative effects and precipitation associated with various DP–RAD categories.
- Evaluate our strength and classification system using other relevant dynamical and thermodynamical quantities (e.g., vorticity, water vapor).
- Incorporate lifetime and evolution information using the developed classification system.

Acknowledgments:

- W. B. Rossow
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- M. Bauer