Is the weather getting weirder?

A physical and statistical study of trends in weather variability

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Motivation

Extreme weather swings are driving New Yorkers nuts

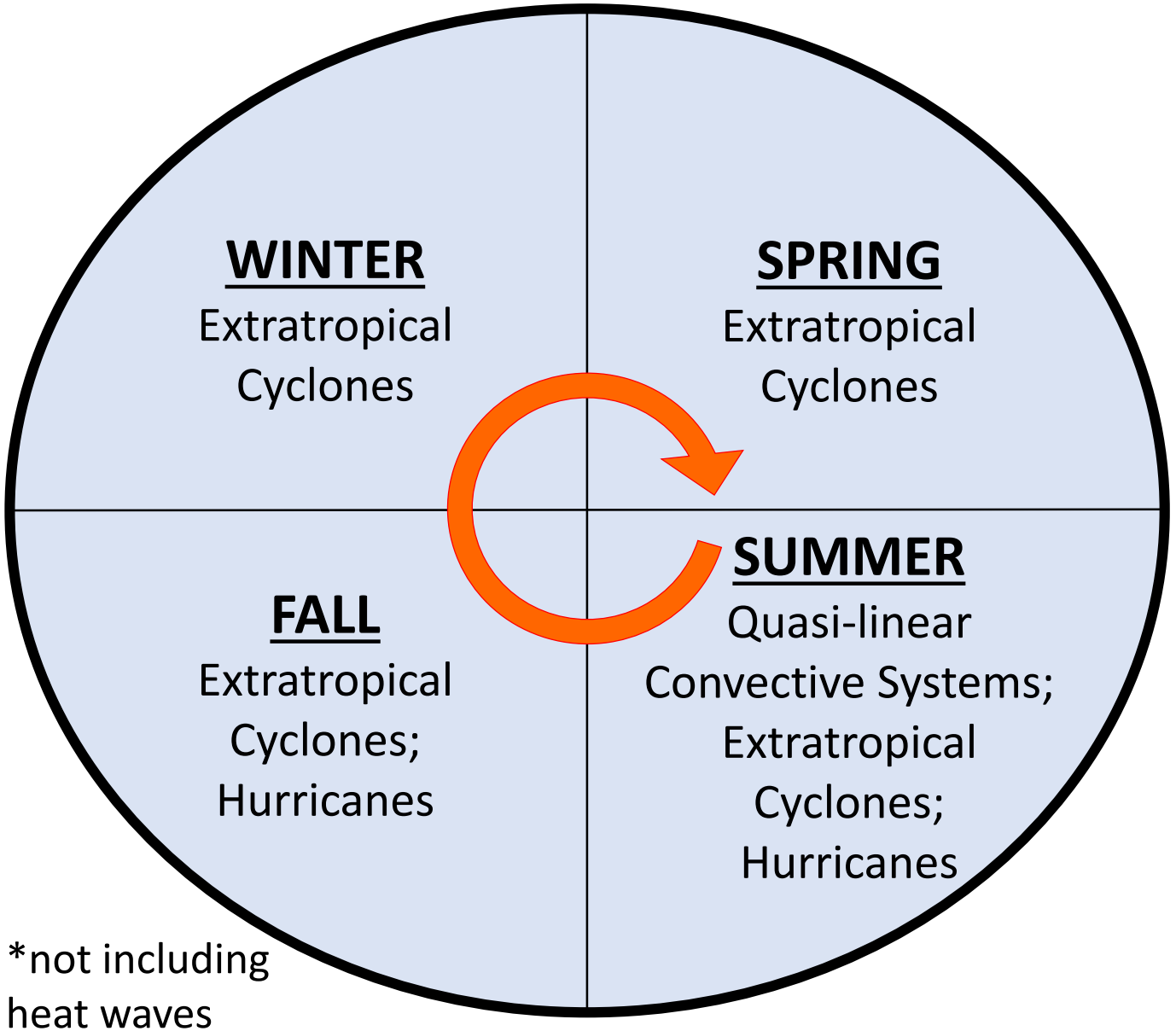
As the Earth continues to warm overall, changes in the Earth's climate are being observed (i.e., extreme weather events, such as heat waves and heavy precipitation events)

How extreme are these events and are they occurring more frequently today than in the past?

Objective

- Examine the annual cycle of temperature and precipitation as well as their associated extremes in the greater NYC region
- Learn some coding techniques (MATLAB)
- Understand statistics and atmospheric physics

The annual cycle for NYC Weather Disturbances*



*not including heat waves

Our Lab: Physics of the Atmosphere - Waves and Blocking

Start off with conservation equations for:

-mass

-momentum

-energy

Navier–Stokes Equations

3 – dimensional – unsteady

Coordinates: (x,y,z) Time : t Density: ρ Pressure: p Reynolds Number: Re

Velocity Components: (u,v,w) Stress: τ Heat Flux: q Prandtl Number: Pr

Continuity:

$$\frac{\partial \rho}{\partial t}+\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0$$

X – Momentum:

$$\frac{\partial(\rho u)}{\partial t}+\frac{\partial(\rho u^2)}{\partial x}+\frac{\partial(\rho uv)}{\partial y}+\frac{\partial(\rho uw)}{\partial z}=-\frac{\partial p}{\partial x}+\frac{1}{Re_r}\left[\frac{\partial \tau_{xx}}{\partial x}+\frac{\partial \tau_{xy}}{\partial y}+\frac{\partial \tau_{xz}}{\partial z}\right]$$

Y – Momentum:

$$\frac{\partial(\rho v)}{\partial t}+\frac{\partial(\rho uv)}{\partial x}+\frac{\partial(\rho v^2)}{\partial y}+\frac{\partial(\rho vw)}{\partial z}=-\frac{\partial p}{\partial y}+\frac{1}{Re_r}\left[\frac{\partial \tau_{xy}}{\partial x}+\frac{\partial \tau_{yy}}{\partial y}+\frac{\partial \tau_{yz}}{\partial z}\right]$$

Z – Momentum:

$$\frac{\partial(\rho w)}{\partial t}+\frac{\partial(\rho uw)}{\partial x}+\frac{\partial(\rho vw)}{\partial y}+\frac{\partial(\rho w^2)}{\partial z}=-\frac{\partial p}{\partial z}+\frac{1}{Re_r}\left[\frac{\partial \tau_{xz}}{\partial x}+\frac{\partial \tau_{yz}}{\partial y}+\frac{\partial \tau_{zz}}{\partial z}\right]$$

Total Energy – Et:

$$\frac{\partial(E_T)}{\partial t}+\frac{\partial(uE_T)}{\partial x}+\frac{\partial(vE_T)}{\partial y}+\frac{\partial(wE_T)}{\partial z}=-\frac{\partial(up)}{\partial x}-\frac{\partial(vp)}{\partial y}-\frac{\partial(wp)}{\partial z}$$
$$+\frac{1}{Re_r}\left[\frac{\partial}{\partial x}(u\tau_{xx}+v\tau_{xy}+w\tau_{xz})+\frac{\partial}{\partial y}(u\tau_{xy}+v\tau_{yy}+w\tau_{yz})+\frac{\partial}{\partial z}(u\tau_{xz}+v\tau_{yz}+w\tau_{zz})\right]$$

Make approximations and wrestle with equations:

-ψ, Stream-function can be thought of as height of a pressure level

-U, background horizontal wind that constantly blows around the rotating earth

$$0=\frac{\partial \nabla^2\psi}{\partial t}+U\frac{\partial \nabla^2\psi}{\partial x}+\beta\frac{\partial \psi}{\partial x}$$

Get wave solutions:

$\psi_0 e^{i(kx+ly-\omega t)}$

-Gravity Waves

-Rossby Waves

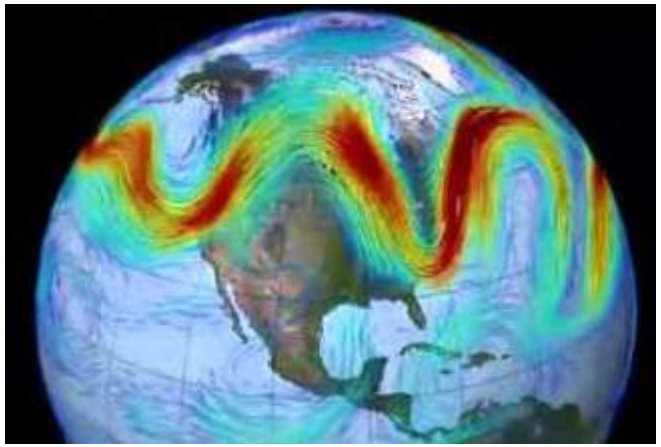
Behave like any other wave:

-Bend/refract

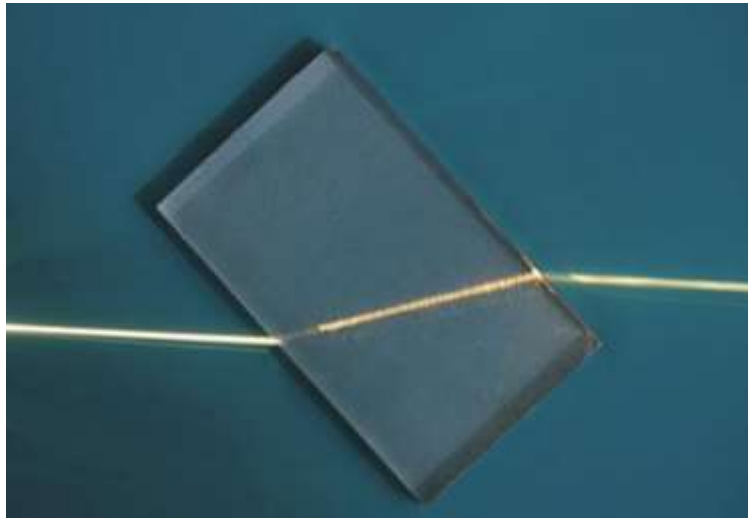
-Interfere

-Break

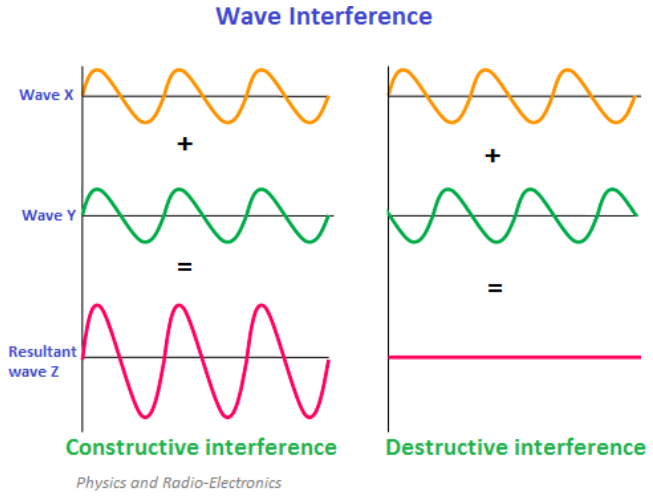
Gravity Waves



Rossby Waves



Refraction of light waves



Wave breaking in the ocean

Research Area: Blocks

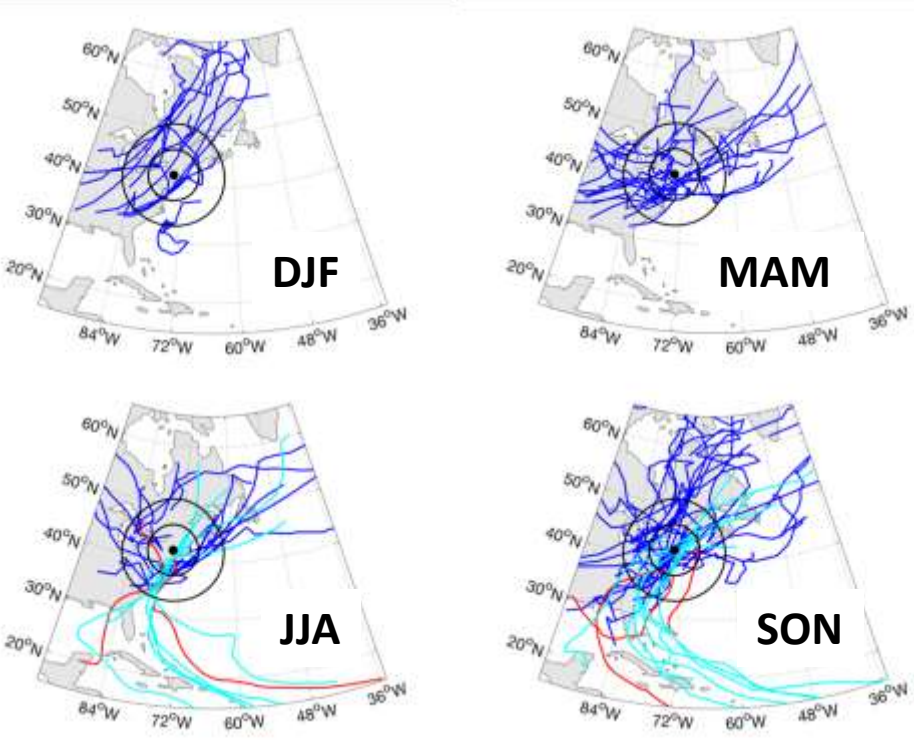
- Associated with Rossby waves interfering and then breaking
- Stationary, high-pressure, extratropical-systems
- Block the normal horizontal flow of wind from spinning planet, redirects the Jetstream
- Persist for up to several weeks
- Associated with weather phenomena such as heat waves[1]
- Can alter the path of storms[2]

Remik Ziemlinski, Climate Central

Spencer Platt, Getty Images

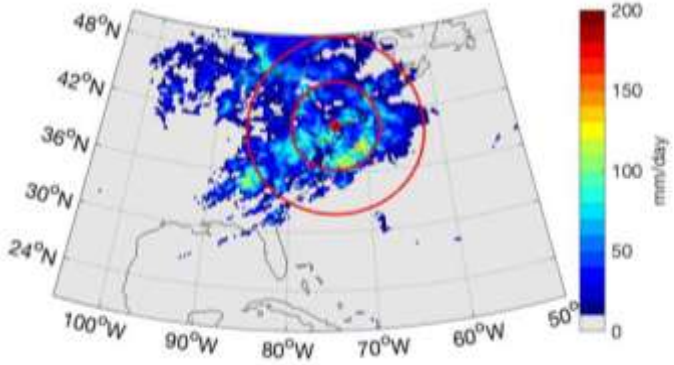
Research Area: Midlatitude Precipitation

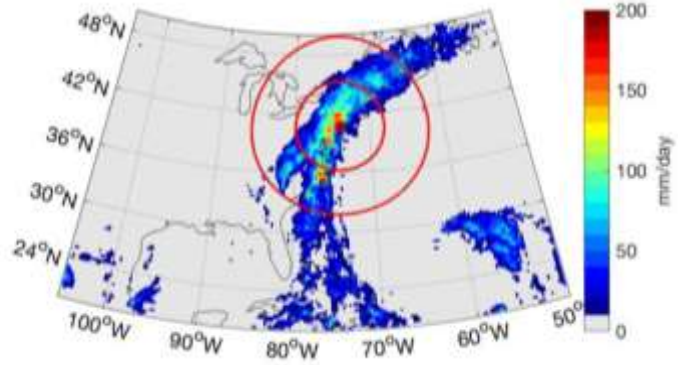
Cyclone tracks



GOES satellite image of an extratropical cyclone

GOES satellite image of Sandy interacting with a frontal system





Atmospheric Ingredients
Vertical Stability
Moisture Flux Convergence
Large-scale Horizontal Motion

+

Cyclones
Extratropical
Subtropical
Tropical

ET

TT

=

Impacts

Precipitation

Questions?

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