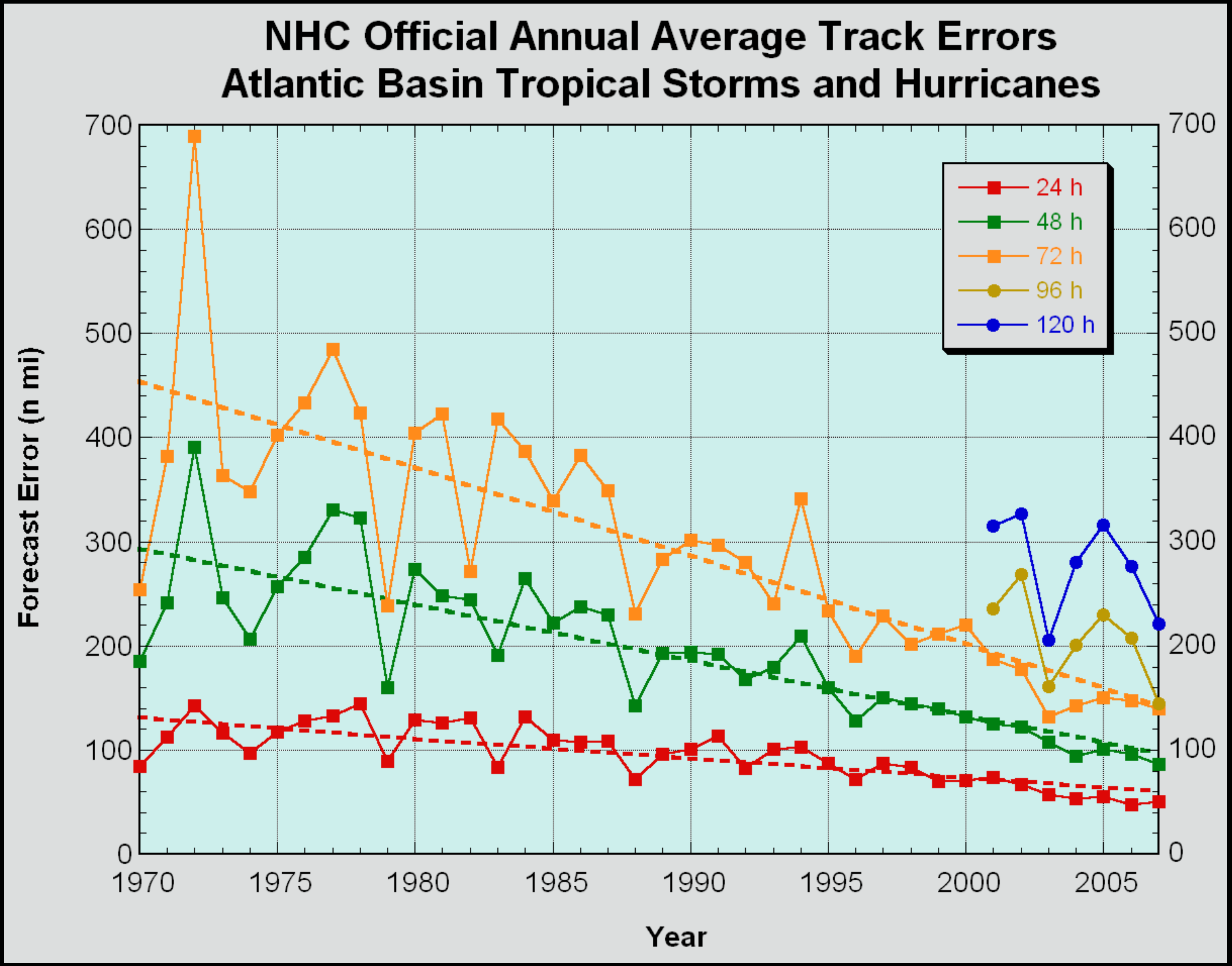
Meteorology – Lecture 24

Robert Fovell

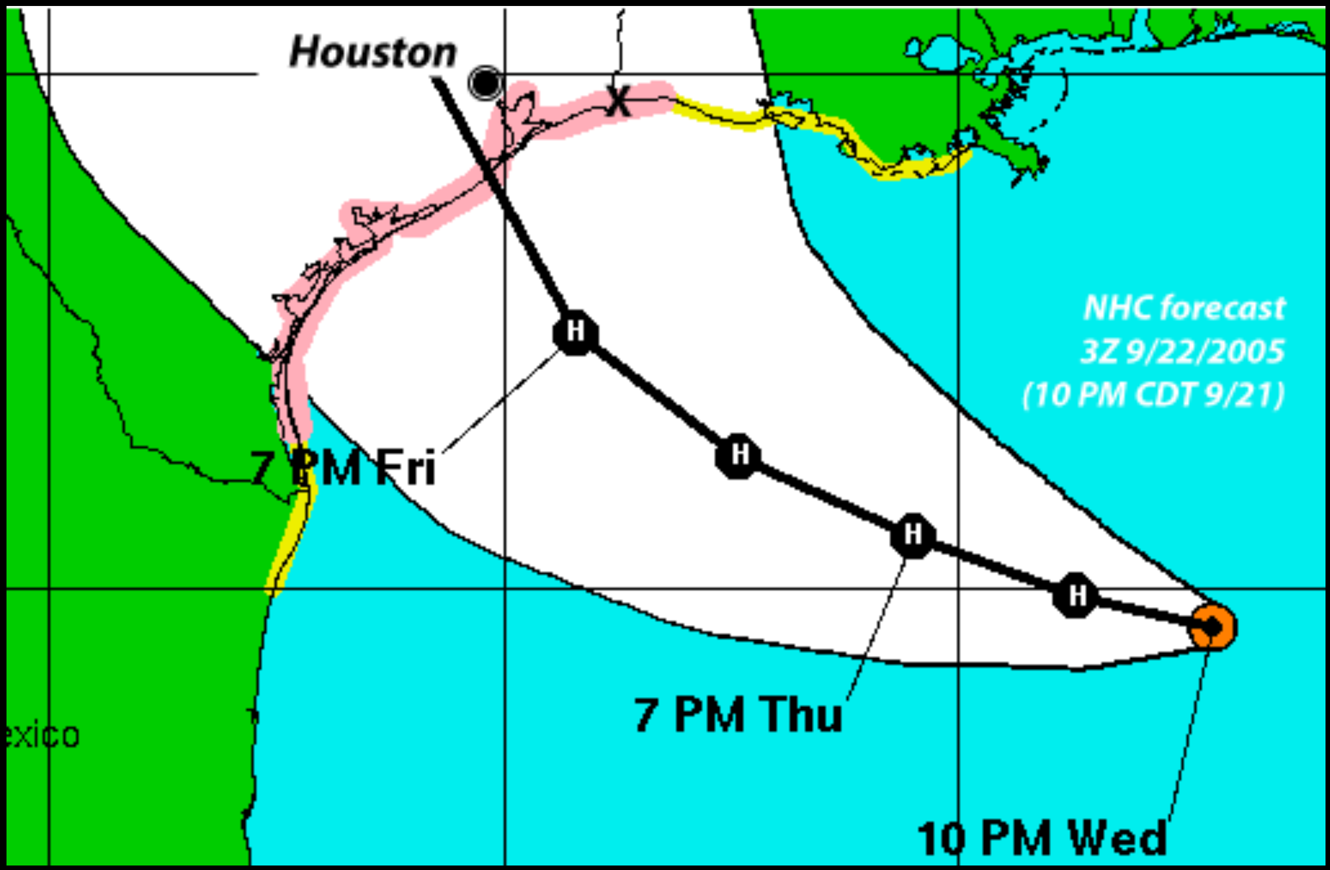
rfovell@albany.edu

Important notes

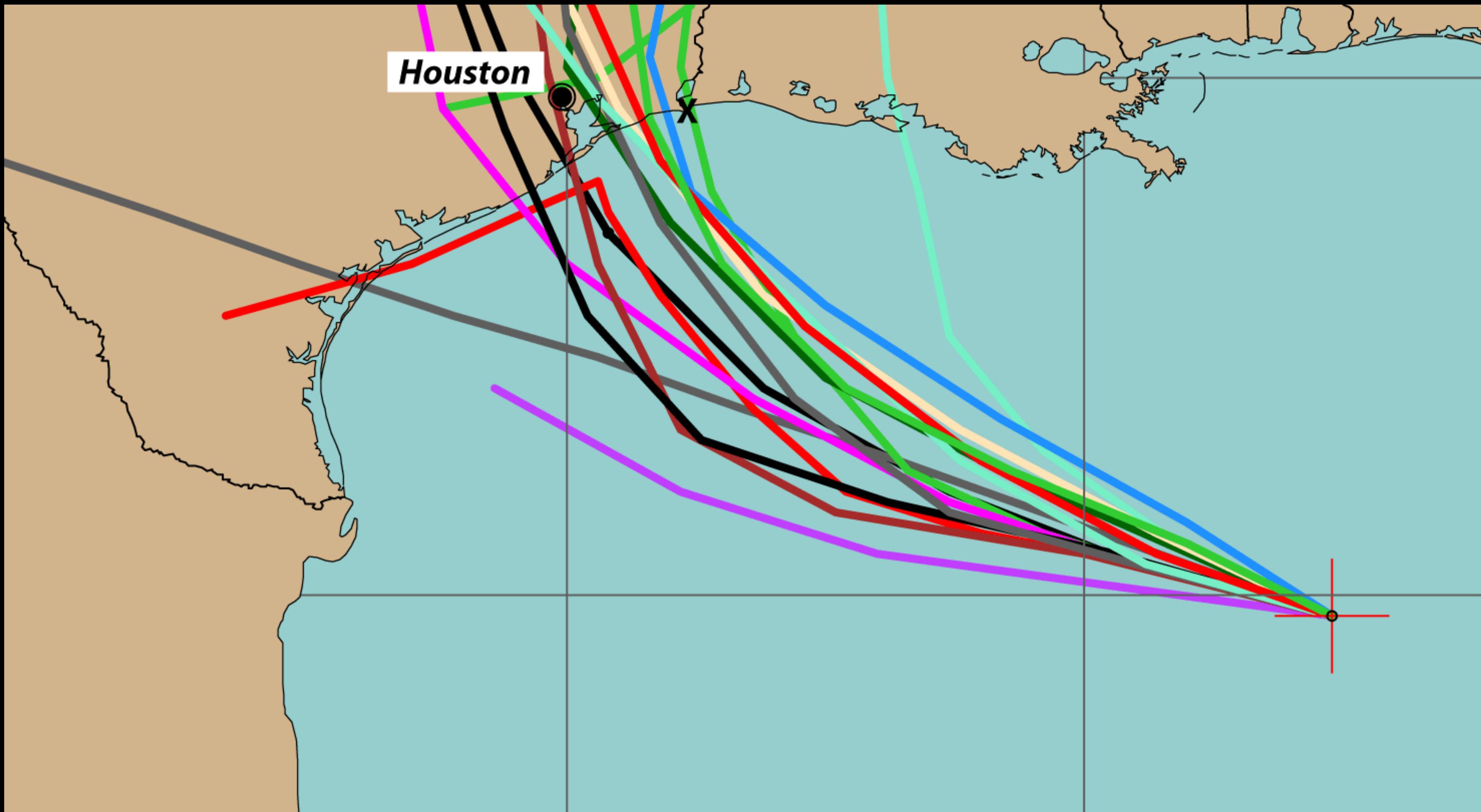
- These slides show some figures and videos prepared by Robert G. Fovell (RGF) for his "Meteorology" course, published by The Great Courses (TGC). Unless otherwise identified, they were created by RGF.
- In some cases, the figures employed in the course video are different from what I present here, but these were the figures I provided to TGC at the time the course was taped.
- These figures are intended to supplement the videos, in order to facilitate understanding of the concepts discussed in the course. *These slide shows cannot, and are not intended to, replace the course itself and are not expected to be understandable in isolation.*
- Accordingly, these presentations do not represent a summary of each lecture, and neither do they contain each lecture's full content.


NHC Official Annual Average Track Errors
Atlantic Basin Tropical Storms and Hurricanes
Forecast Error (n mi)
Year
24 h
48 h
72 h
96 h
120 h
0
100
200
300
400
500
600
700
1970
1975
1980
1985
1990
1995
2000
2005

Hurricane Rita (2005)



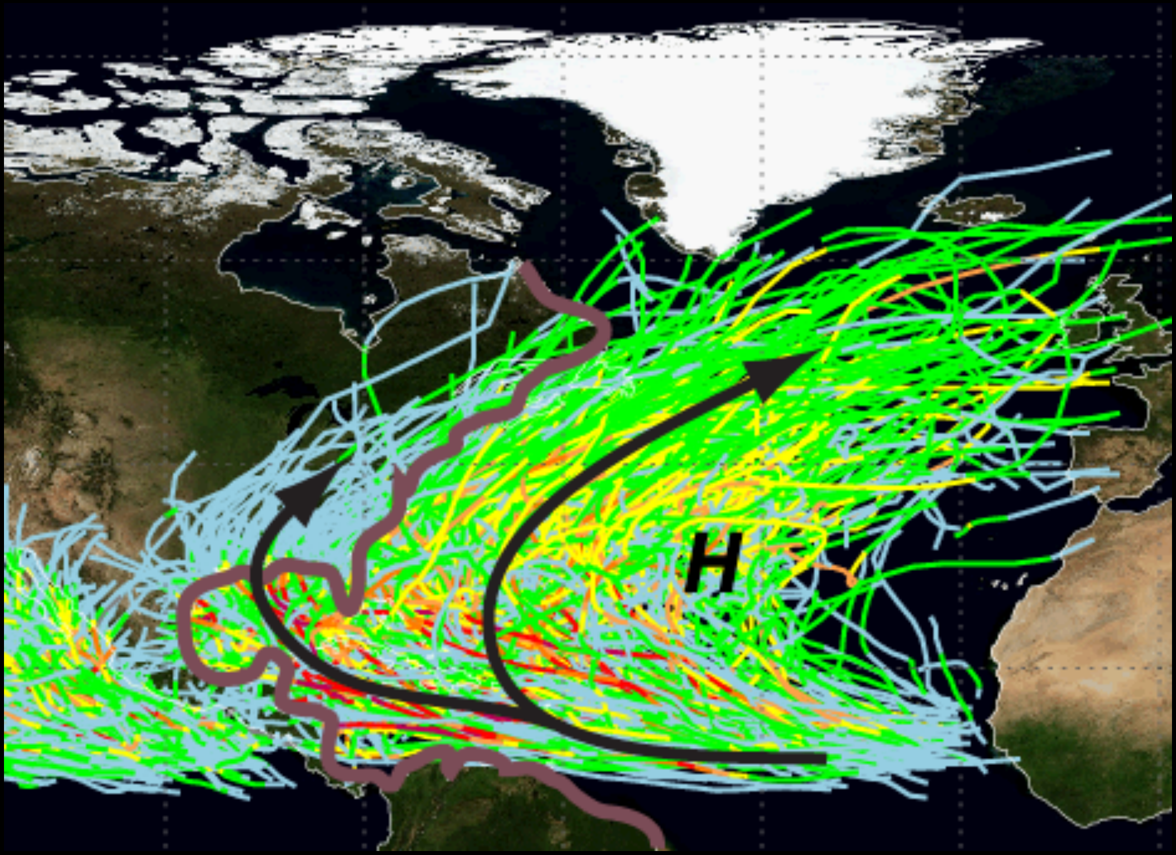
National Hurricane Center (NHC) forecast track for Hurricane Rita, issued 3Z 22 September 2005, about 54 h prior to landfall.



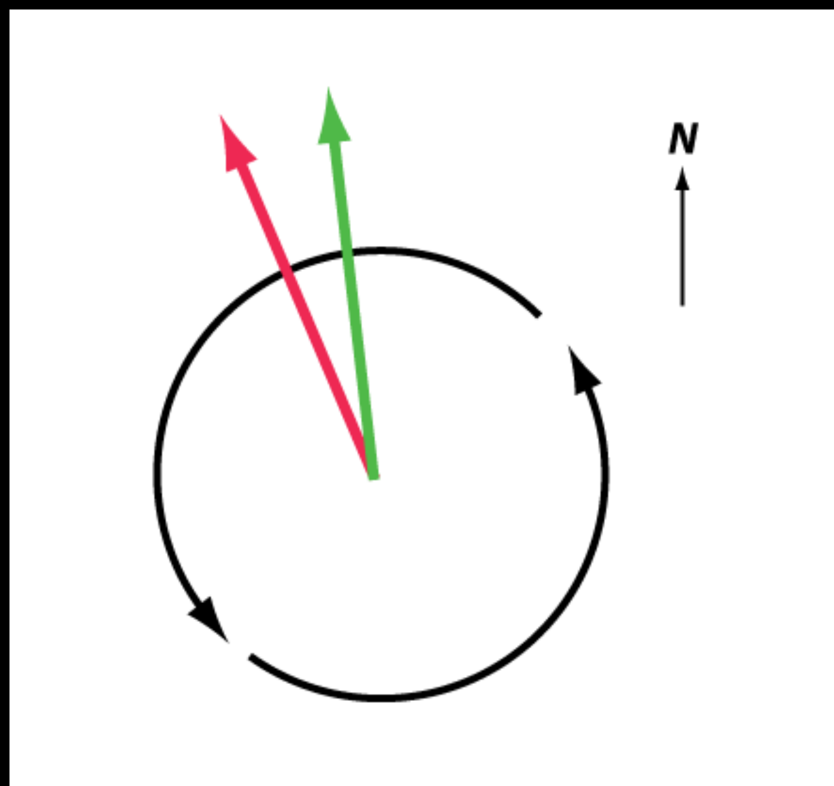
An ensemble of forecasts for Rita's track, made at the same time.
Actual landfall marked by "X".

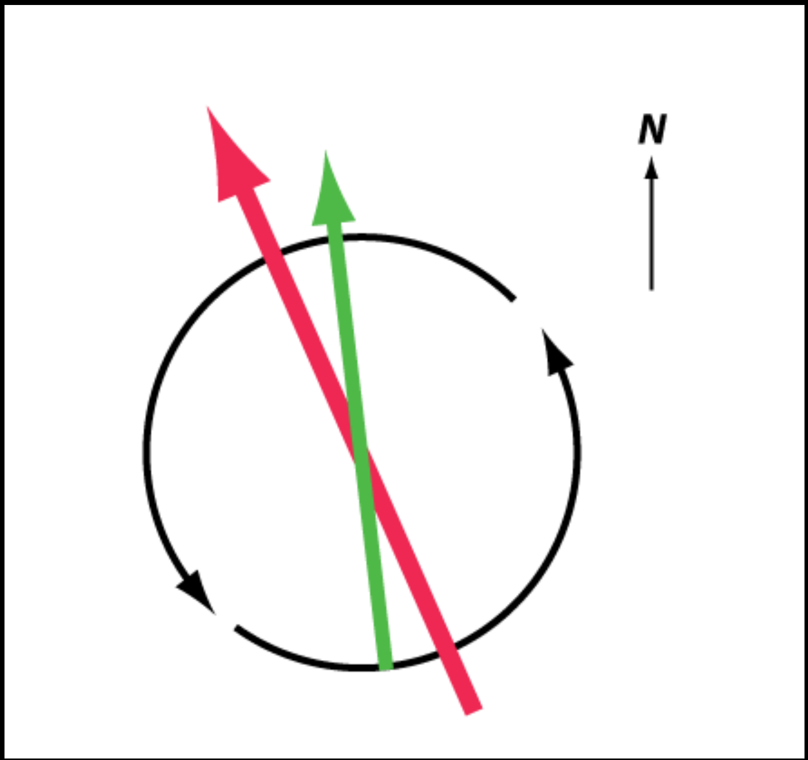
Hurricane motion: steering

Steering from Bermuda High



Two models that place the Bermuda H in slightly different positions, having slightly different intensities, will put slightly different winds across the hurricane vortex, possibly giving them distinct trajectories. Now picture those trajectories being extrapolated in time. In this way, minor differences can quickly grow to become major.



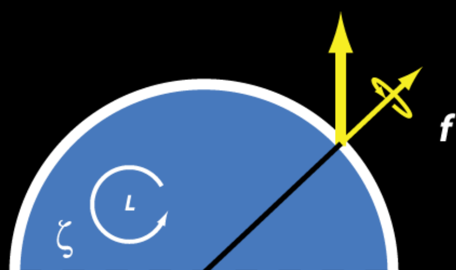


- Storm **depth** may influence the track owing to vertical wind shear -- the horizontal wind changing direction and/or speed with height

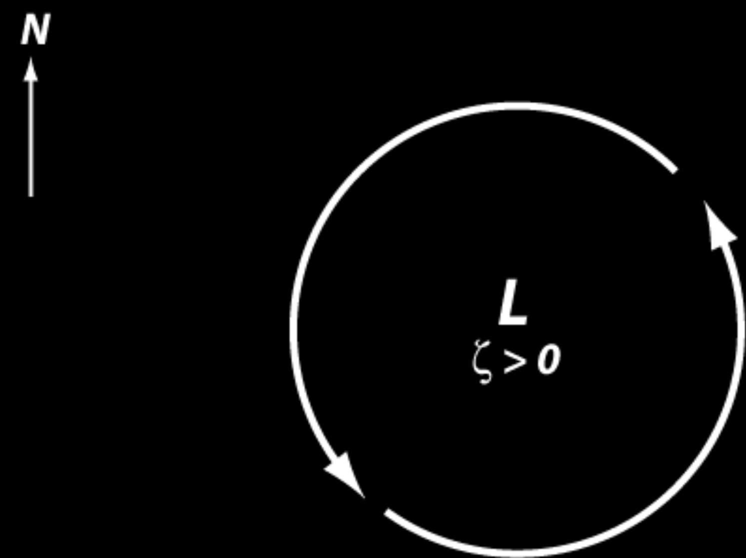
- We recall that hurricanes don't like vertical shear too much, but it's hard for them to avoid shear completely… especially as they move into the midlatitudes where horizontal T gradients are larger

Hurricane motion: beta effect

Planetary and local spin

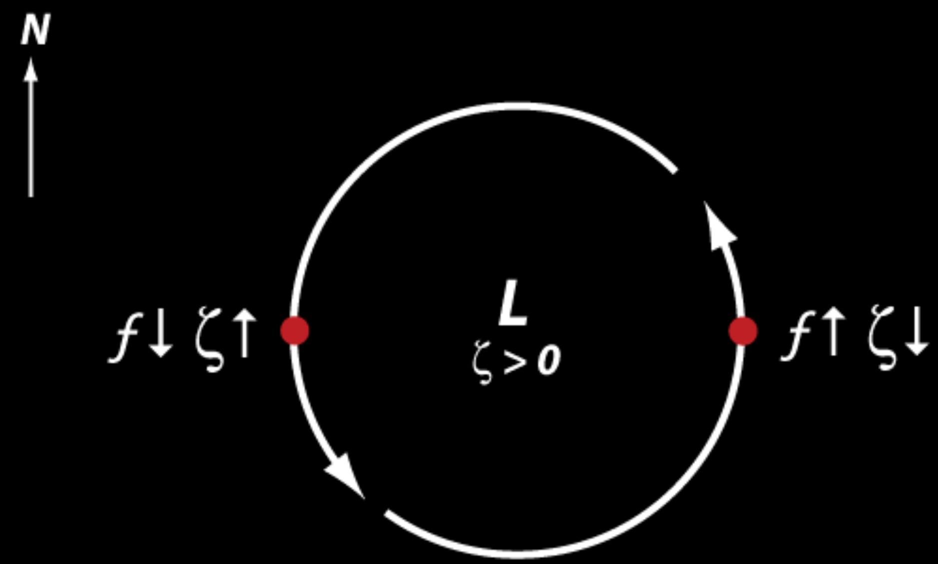


- Recall planetary vorticity (Coriolis effect) is *f*, and Earth-relative vorticity is “zeta” (ζ)
- Also recall that *f* increases with latitude away from the Equator where Coriolis vanishes
- ...and that absolute vorticity… *f*+zeta… is conserved in the absence of sources and sinks



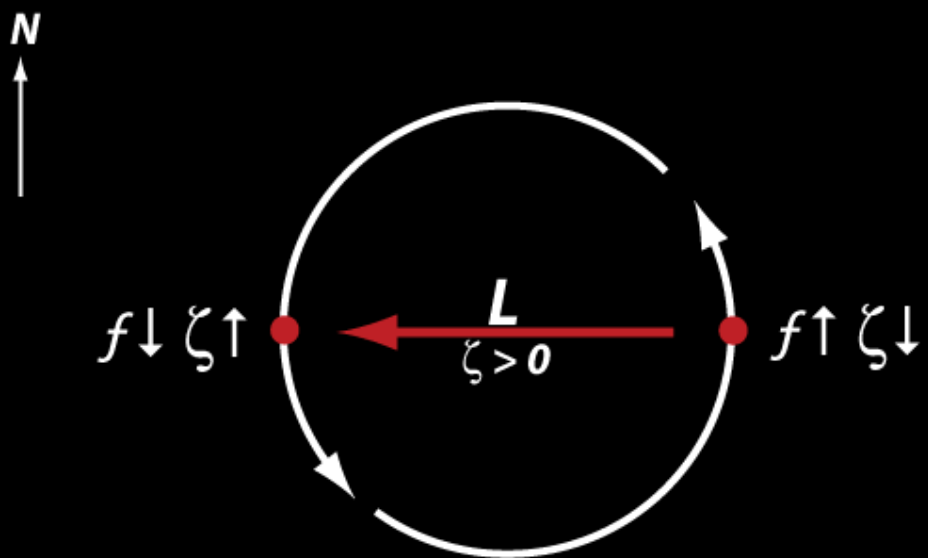
So, let's consider our hurricane. North is on top.

It's a cyclone with positive relative vorticity.
Zeta is positive, just like *f*.



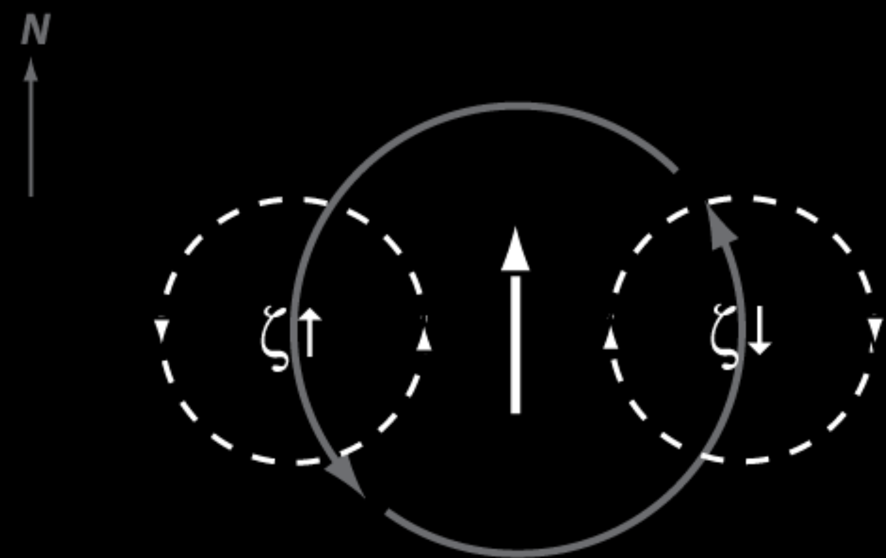
On the cyclone's west side, air is moving equatorward. It's planetary vorticity is **decreasing**. But absolute vorticity is conserved, so its relative vorticity there must be **increasing** to compensate.

Similarly, on the east side, zeta is decreasing to compensate the increase in *f*.



So there’s already a tendency for the cyclone to shift westward, towards where the positive relative vorticity is increasing, which has nothing to do with the large-scale winds.

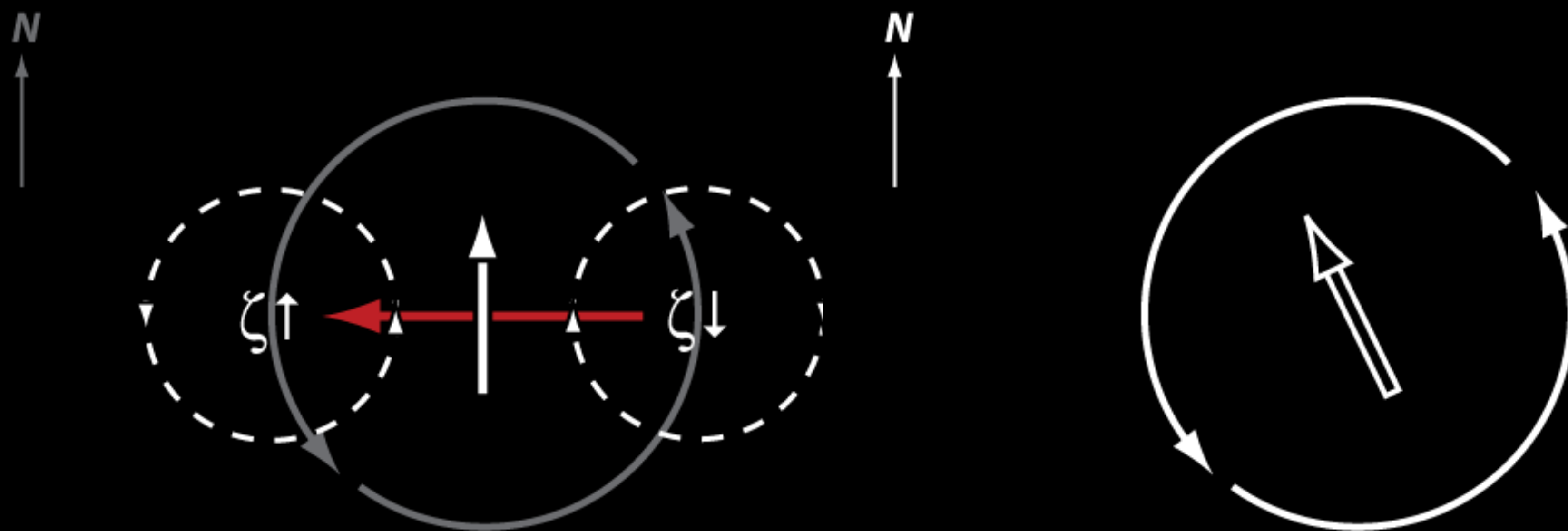
But wait, there’s more!



Those relative vorticity changes induce circulations -- CCW where vorticity is increasing, CW where it's decreasing.

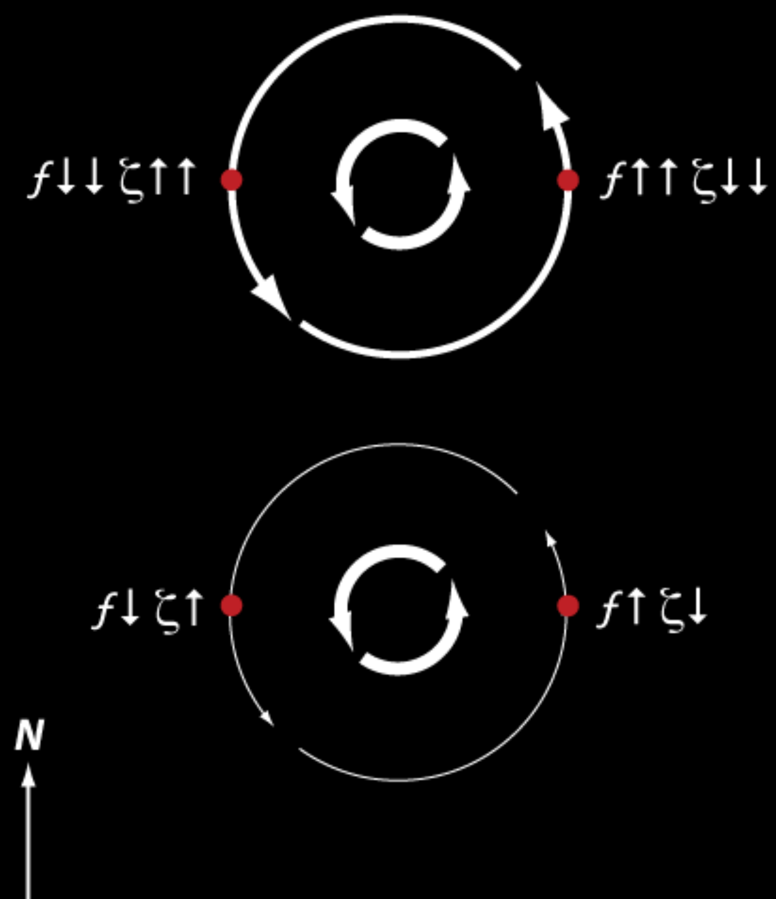
Further, those circulations combine to cause a wind to develop **across** the vortex, directed towards the NORTH. A wind that didn't exist before. A wind that only exists because the Earth is curved.

This, by ITSELF, will tend to move the vortex POLEWARD.



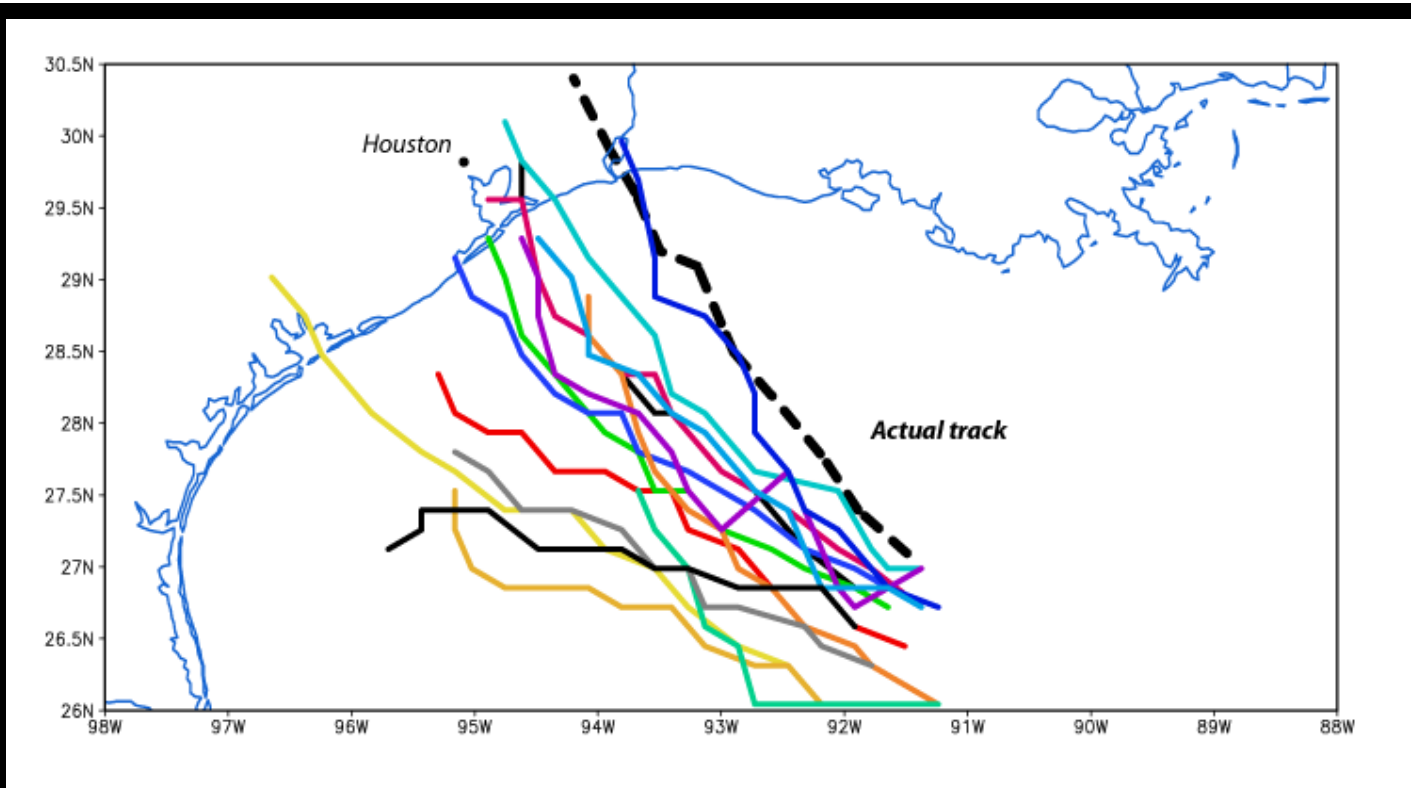
The combined effect of those westward and northward tendencies, along with CCW advection around the cyclone, induces a NW-ward motion in the vortex, even if the environmental winds are calm.

TCs born in the tropical central Atlantic naturally want to move towards *us* in the U.S.. This is called “beta drift”, or the “beta effect”.



Because the beta effect depends on the winds that are far beyond the eye, **storm width** also matters. Picture two hurricanes. They have equal fury near the center, but one has stronger winds 200, 300, 400 km and more outward from the core. Those winds are CCW also and part of the hurricane circulation.

Hurricane Rita and cloud microphysics



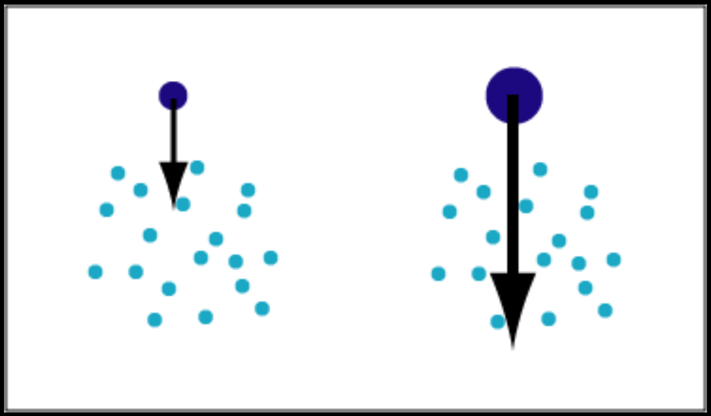
Here are 15 model forecast tracks, as well as Rita's actual path. These model runs used 30 km grid boxes. These runs started when Rita was 54 h out from land, but I'm just showing you the last DAY's motion -- and that's why the tracks aren't starting all at the same place.

Most of the tracks are too far west, and make landfall near Houston, much like the NHC model tracks I showed you earlier. These tracks varied owing to differences in **cloud microphysics assumptions**.

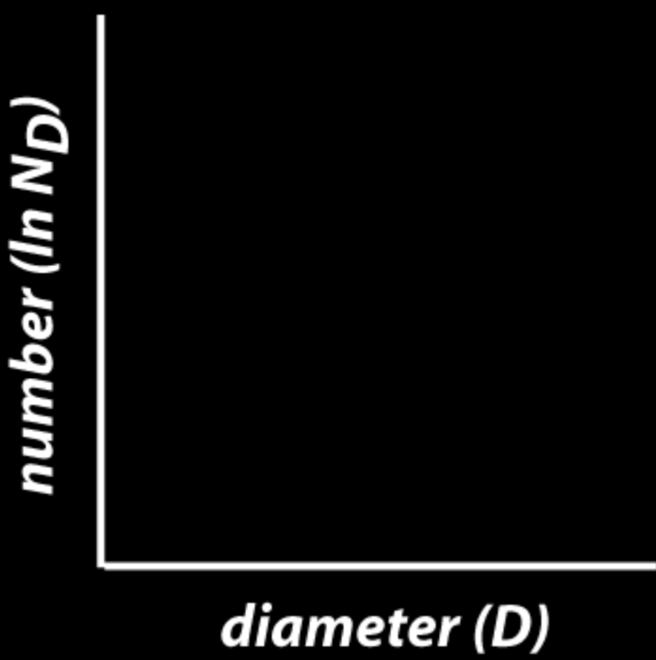
Cloud microphysics is concerned with the behavior and interaction of condensed water particles. These come in many different shapes, sizes, and types.

An important characteristic is particle size as that determines both fallspeed and growth rate.

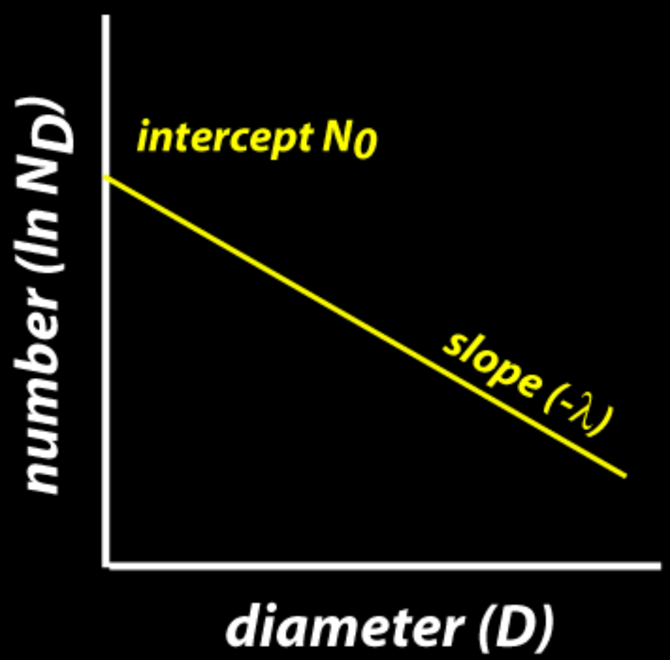
Picture two raindrops -- one small, one large -- falling through a cloud of smaller cloud droplets. Owing to their greater weight, the raindrops are falling faster than the droplets, and as a result collisions are taking place that lead to further raindrop growth.



We cannot follow every condensation particle. A common compromise is to presume we have exponentially fewer LARGER drops than SMALLER ones. So picture a plot of the number of particles vs. diameter. The vertical axis is the LOG of the number, so an exponential relationship will appear as a straight line.

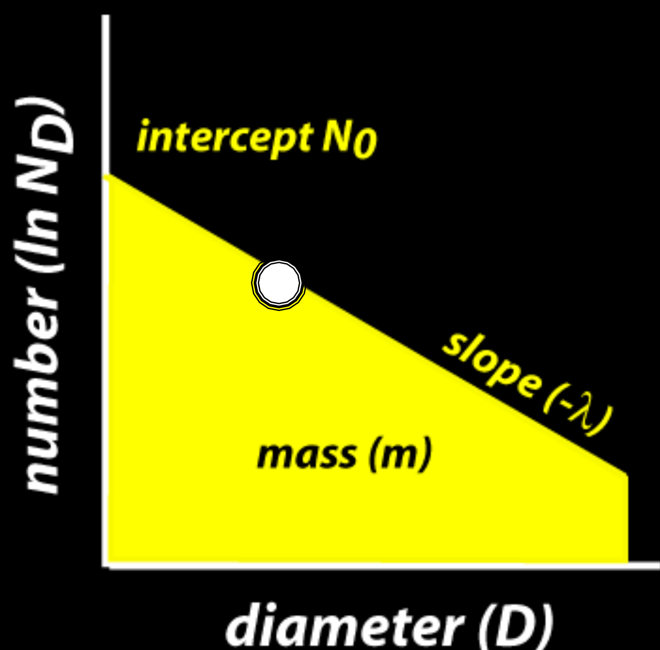


We can characterize this distribution with two parameters… its SLOPE and its INTERCEPT.

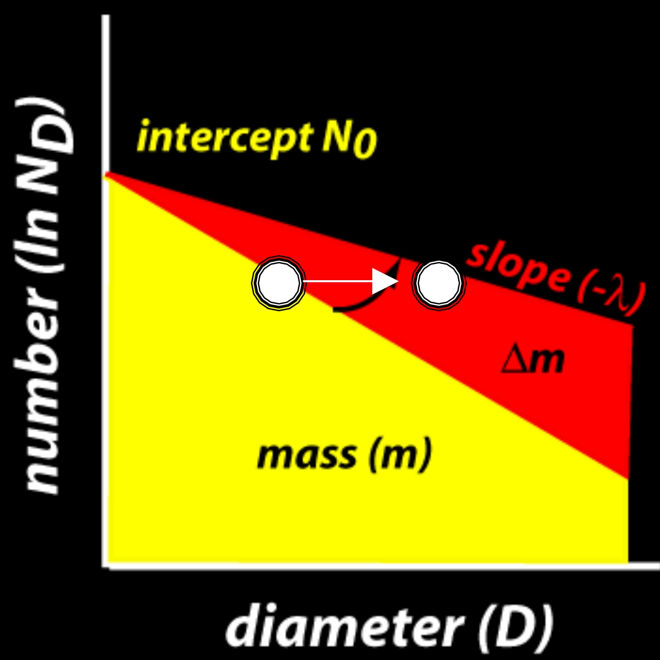


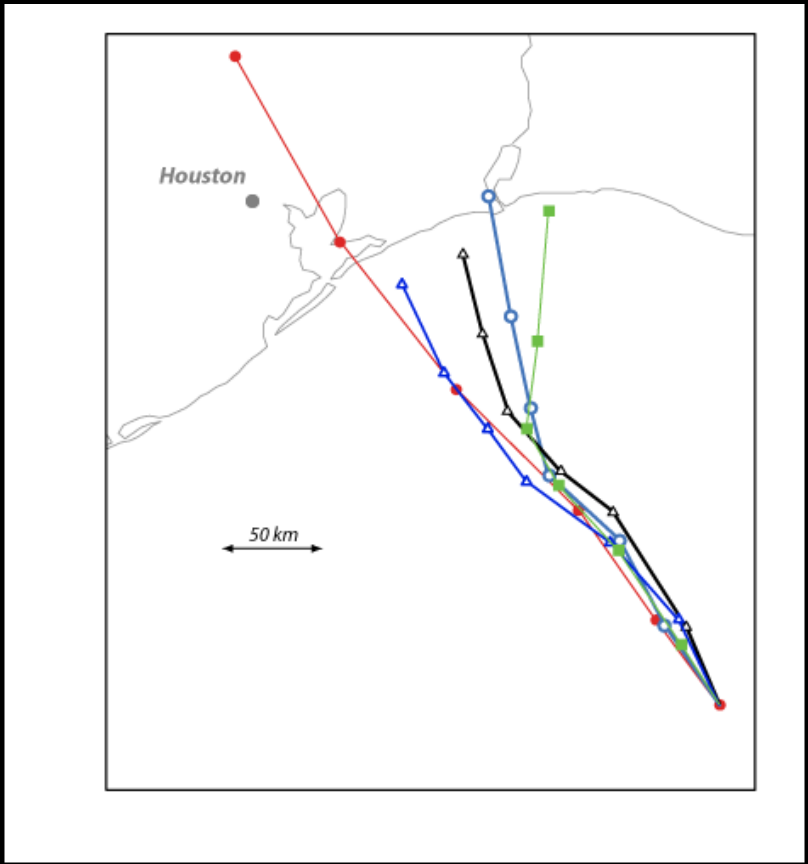
The total rainwater MASS in our volume is the area beneath the curve. From this, we can calculate the mass-weighted average particle diameter.

I know the density of liquid water, so the average diameter tells me its mean weight and how quickly it falls on average. This reduces incredible complexity to something much simpler (and cruder).



Many times, we presume the intercept is fixed.
So if the total drop mass increases, that increases the AREA under the curve and our distribution pivots upward. There's more large particles now. They fall even FASTER on average.
This is only the beginning... Assumptions that lead to **uncertainty**.





- Here's an ensemble of forecast tracks in which only some microphysical assumptions were varied … such as how quickly snow crystals fall or how fast cloud droplets develop into rain
- That rapidly resulted in different storm tracks!
- The reasons are complex, but an important element is they changed storm size.

[end]