



The University of Georgia

An Overview of Synoptic and Mesoscale Factors Contributing to the Disastrous Atlanta Flood of 2009

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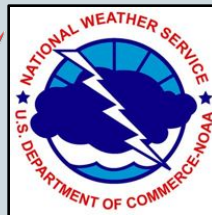
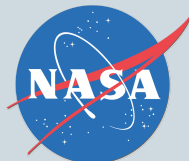
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What I Am I Going to Talk about

- 1.! Overview of the Flood Event: The Human Toll
 - 2.! The Event: A Hydrometeorological Extreme in a Major Urban Center
 - 3.! Synoptic and Hydrometeorological Set-up
 - 4.! Unique, Multiple Perspectives on the Rainfall Totals
 - 5.! Possible Mesoscale Forcing (Orography, Boundaries, Urban Effects?)
 - 6.! Larger Climate Context
-

The Human and Economic Toll

- 10 fatalities, ~100 rescues (many swift-water)
- \$500m +damages
- ~1500 evacuated, ~400 sheltered
- ~20,000 homes/businesses flooded
- ~1500 schools closed, 1 school heavily flooded
- ~300 roads closed/destroyed
- 15 state highways closed
- 17 state highway bridges closed
 - Hwy 166 bridge will take 1 year to rebuild
- I-20 closed (both lanes) west of Atlanta
- I-575 closed (both lanes) at hwy 92
- Stone Mountain Freeway closed (both lanes)
- Water service failed in several counties
- ~5 hazardous materials responses
- 21 Category One dams damaged
- At least 16,000 inquiries/requests for federal aid

Sources: NWS (Nelson, Frantz), GEMA,
AJC



Urban Flooding: Context

- ! Damage, loss of life, and costs from flooding have risen in recent decades (Ashley and Ashley 2008, Brissette et al. 2003).
- ! Seager et al. (2009) recently noted that regions of the southeastern U.S. face increasing vulnerability to hydroclimatic extremes because of population growth and increasing population density.
- ! In 2008, a majority of the population lived in urban areas, and by 2030 this number is expected to reach 81% (UNFPA, 2007). The unsustainable, modified water cycle will affect the ecosystem, infrastructure, and societal activities.
- ! Burian and Shepherd (2005) and Reynolds et al. (2008) represent a sample of recent literature that has reconsidered implications of precipitation on urban drainage and hydrological processes.

How Extreme is Extreme?

- ! COOP station in Canton, Georgia recorded a total of *435.3 mm of rainfall over the period. 300+ mm common*
- ! September 2009 (227.0 mm) were *219% above normal* at Hartsfield-Jackson Atlanta International Airport.
- ! Extremely wet Septembers or extreme flood events may often be associated with weakening tropical systems (Shepherd et al. 2007, Schumacher and Johnson 2006).
- ! September 2009 was *the fifth wettest in Atlanta's history and the fourth wettest for Athens, Georgia*. There were other record totals across North Georgia as well (NWS)

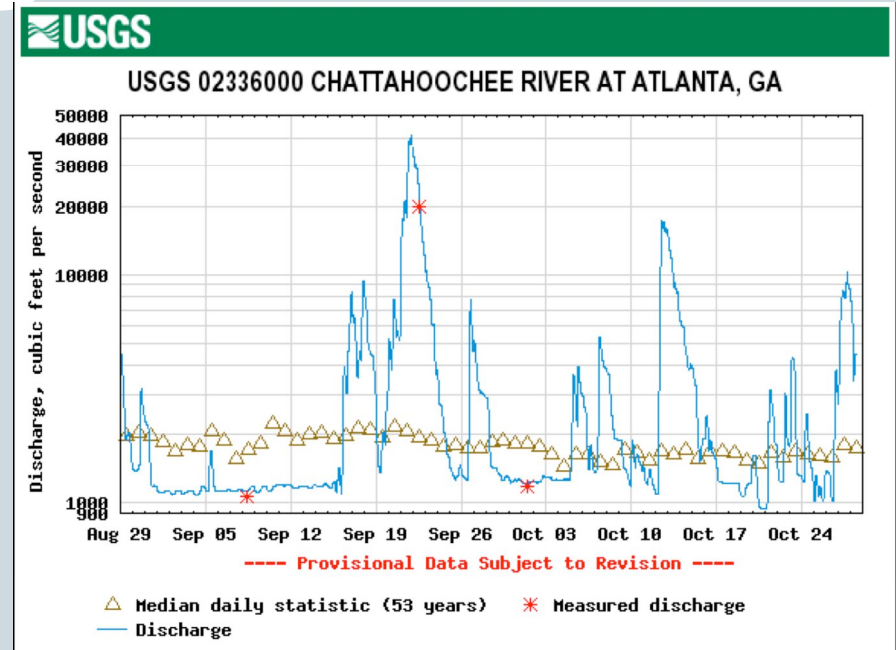
Table 1-8-day rainfall totals across the area from 14 September 2009 to 22 September 2009. The National Weather Service and CoCoRaHS Network provided the data. (Note: 1 inch = 25.4 mm).

Station	Rainfall Totals (mm)
Athens (ASOS)	221.4
Cartersville (ASOS)	187.4
Columbus (ASOS)	81.7
Gainesville (ASOS)	260.8
NE Atlanta (ASOS)	335.0
Peachtree City (ASOS)	128.2
Rome (ASOS)	148.8
West Atlanta (ASOS)	173.2
Canton (COOP, Lead author's home town)	435.3
Alpharetta (COOP)	232.1
Doraville (COOP)	325.5
Dacula 2.1 SSW (CoCoRaHS, Lead author's current residence)	325.6
Carrollton (CoCoRaHS)	331.7
Kennesaw 5 SW (CoCoRaHS)	517.4
Douglasville 4 S (CoCoRaHS)*	461.8

* Rainfall likely underestimated due to gage overflowing.

How Extreme is Extreme?

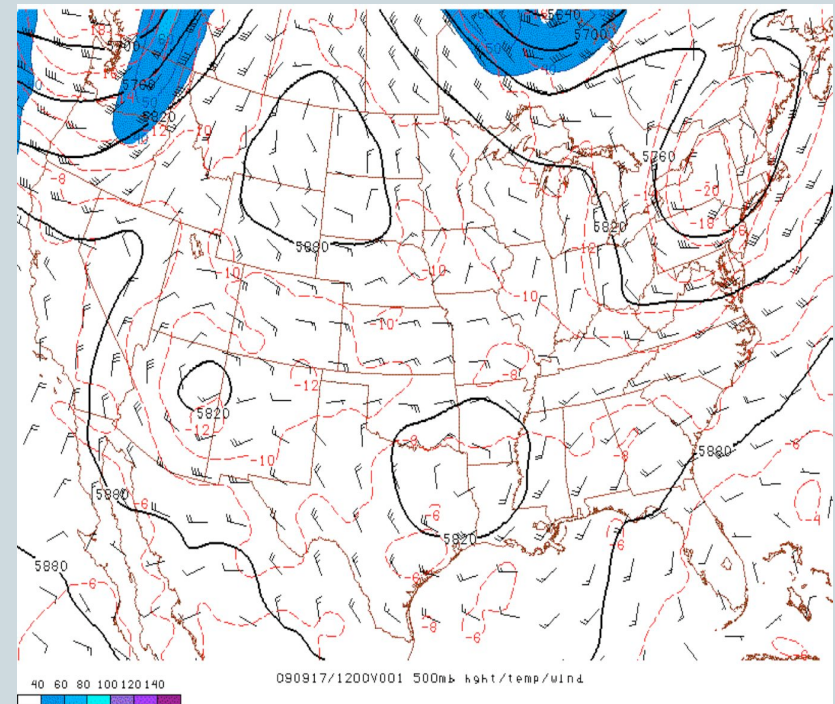
- ! The USGS measured the largest flow ever recorded on Sweetwater Creek near Austell
- ! Parts of Cobb and Douglas Counties were inundated to levels exceeding the estimated 500-year flood
- ! The Yellow River stream gauges in Gwinnett, DeKalb and Rockdale Counties measured flows that submerged the 100-year
- ! The USGS recorded 100-year flood levels on the Chattahoochee River at Vinings in Atlanta (right→), where flooding was the second or third highest on record



The 100-year flood level with a 1% chance of occurrence is one of the standards that the Federal Emergency Management Agency (FEMA) uses to set flood insurance rates and prevent flood plain development.



- ! SE Cut-off Lows (COLs) are rare, particular as flood producers.
- o! Gamble and Meentemeyer (1997) found that frontal systems associated with synoptic features (upper air disturbances) were the dominant mechanism for unseasonal heavy rain events in northern Georgia.
- o! Tropical Cyclones also flood producers (Shepherd et al 2007)
- ! BUT, the primary role of the COL was as an antecedent rainfall source leading up to the flooding event of 20-21 September.

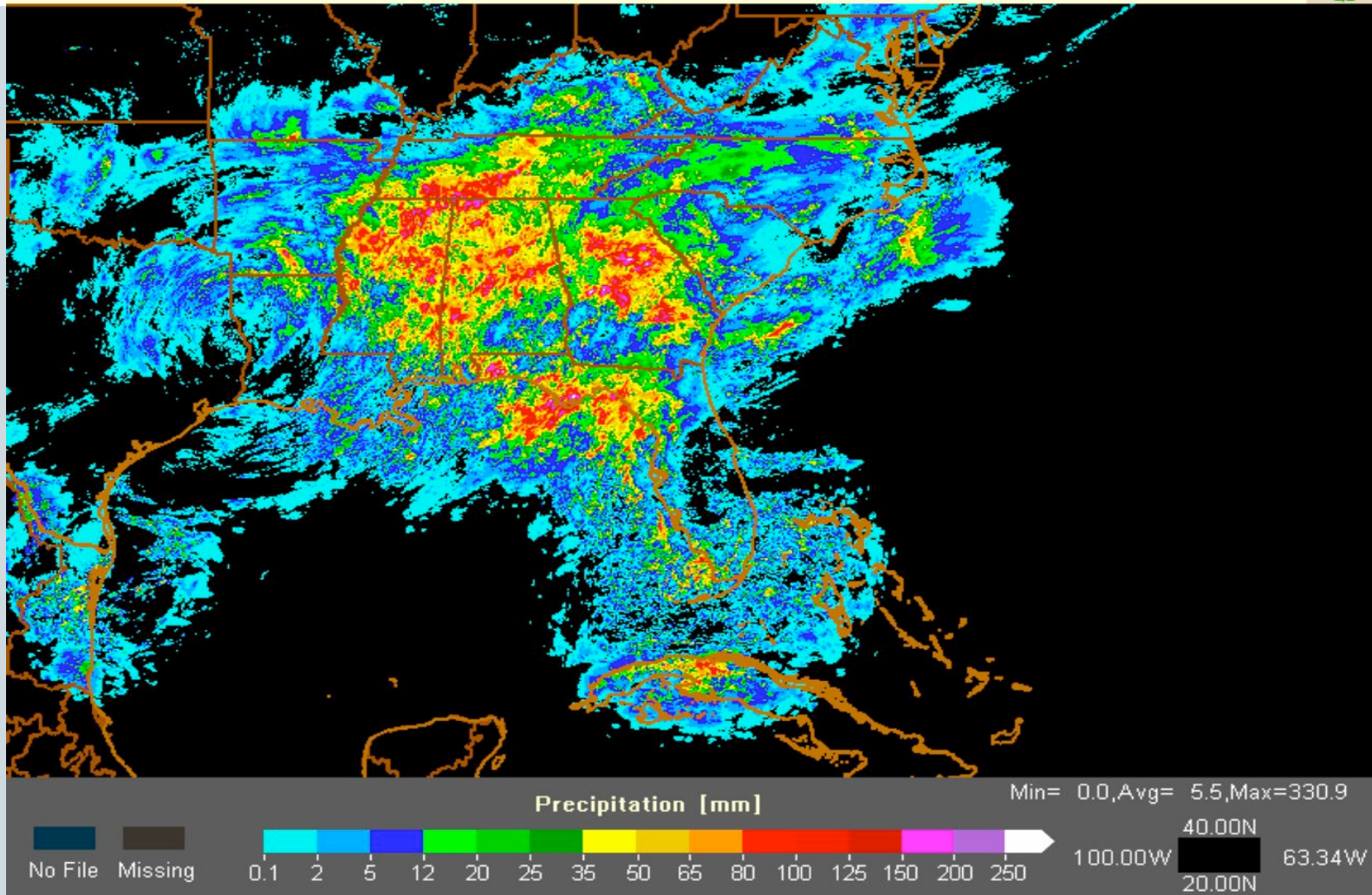




COL and Antecedent Moisture

Q2 [Gauge Adj Rad]
72hr QPE Accumulation

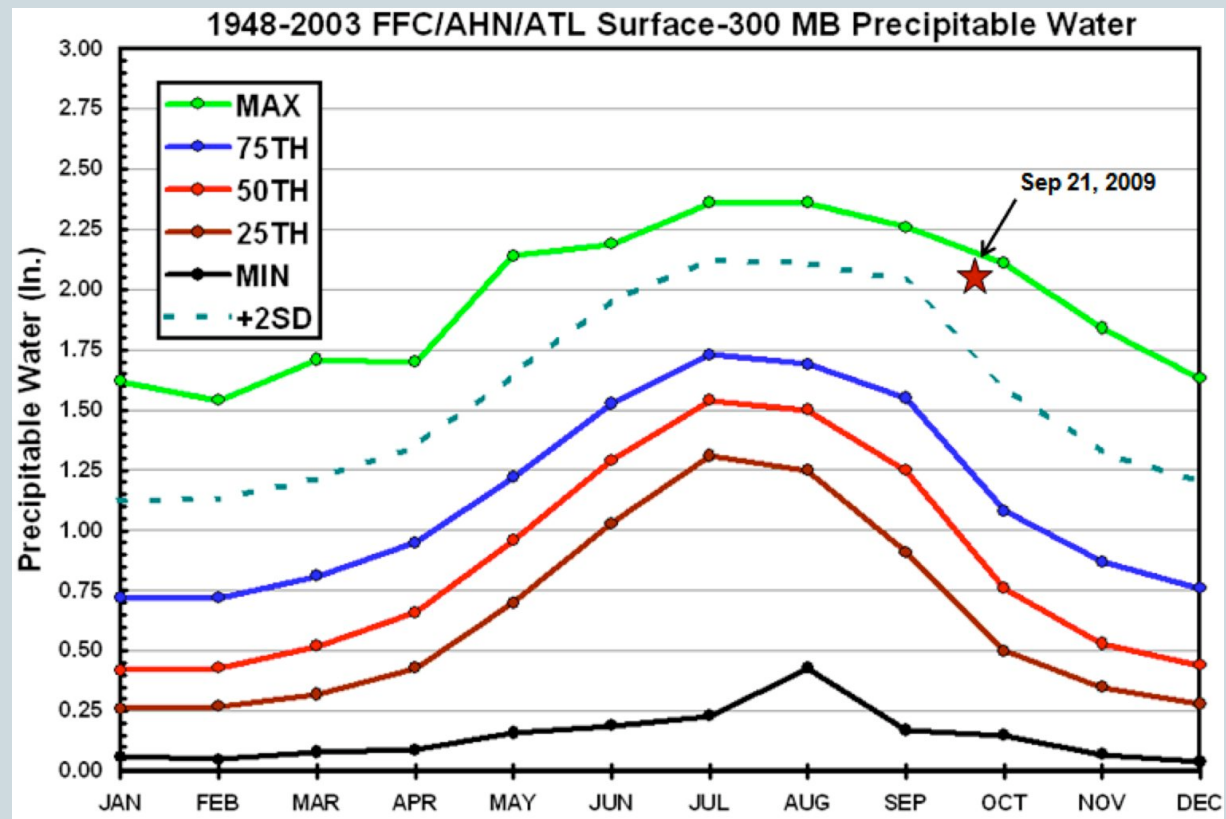
Valid Period:
09/16/2009 20:00:00 - 09/19/2009 20:00:00 UTC



Ample Moisture

!Moisture was quite high.

!Source?



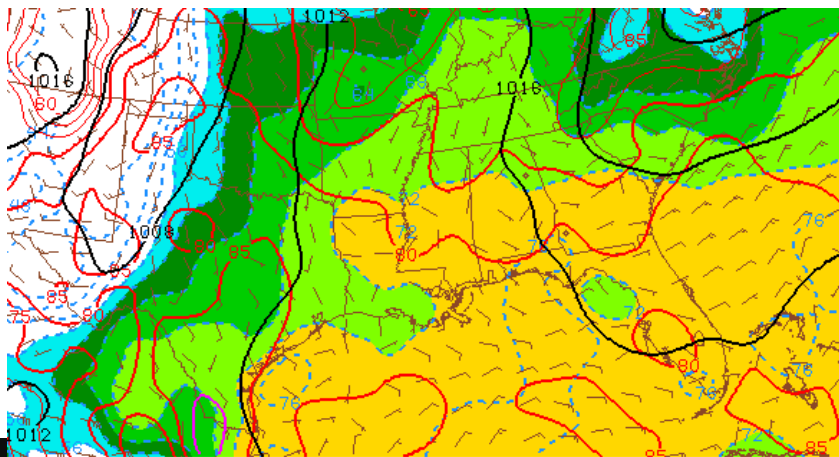
Tropical Connection?

10

- ! Remnants of Hurricane Fred?/
- ! Atlantic Moisture

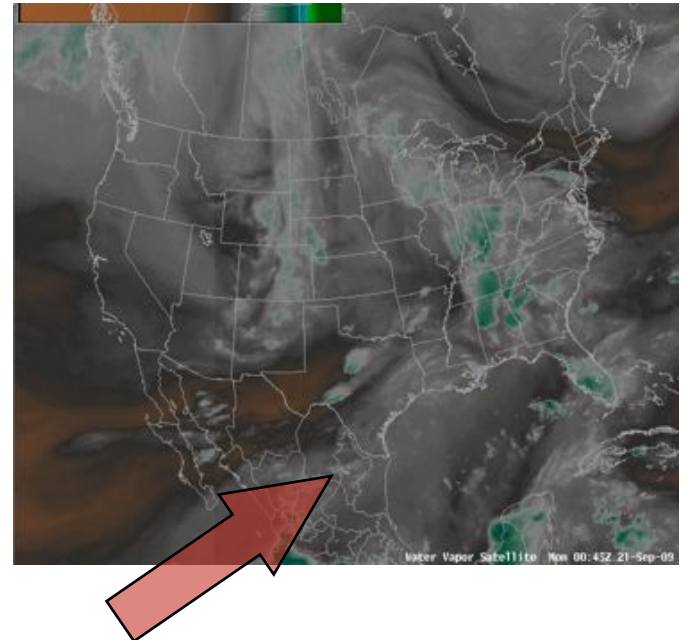
TROPICAL WEATHER OUTLOOK
NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL
200 PM EDT SUN SEP 20 2009

A SMALL AREA OF LOW PRESSURE...ASSOCIATED WITH THE REMNANTS OF FRED...IS LOCATED ABOUT 350 MILES EAST-NORTHEAST OF THE NORTHWESTERN BAHAMAS AND IS MOVING WEST-NORTHWESTWARD AT AROUND 10 MPH. TROPICAL CYCLONE FORMATION IS NOT EXPECTED DUE TO UNFAVORABLE UPPER-LEVEL WINDS.



090921/0000 Surface temp, dewpoint, and pms1

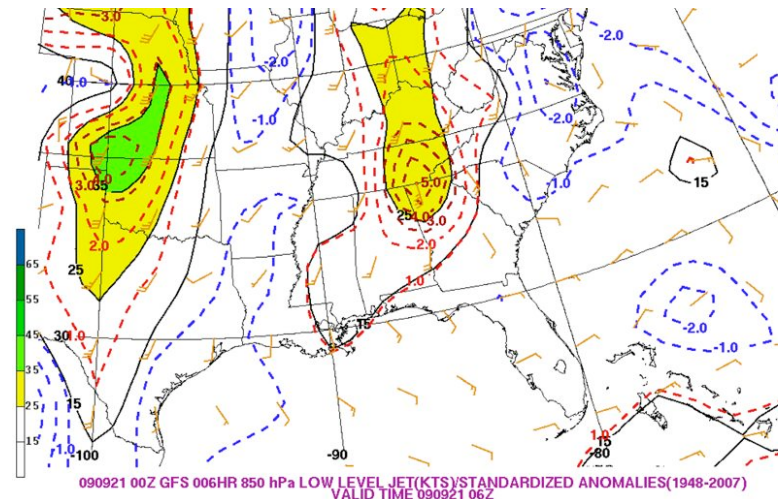
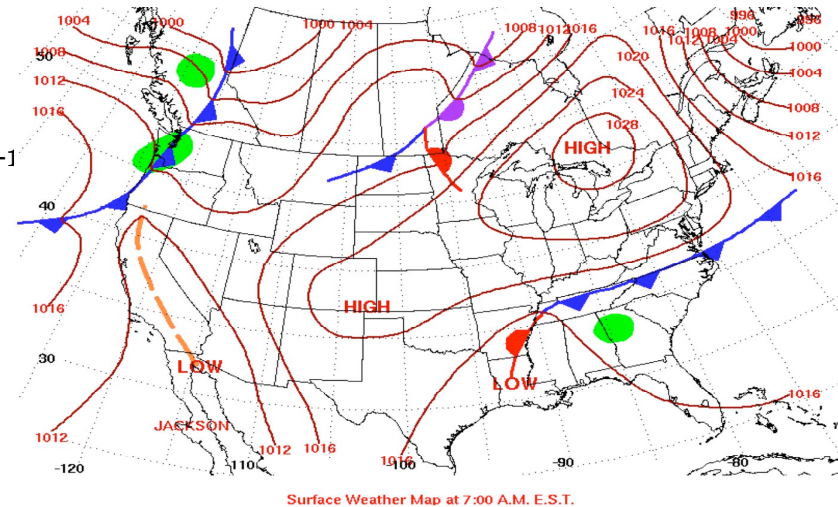
- Moisture from TS Marty transported into SE US





So what happened on 20-21 September?

- ! Ample moisture, moderate instability (Surface-based CAPE values near 1539 J kg^{-1} at Peachtree City at 1200 UTC on 21 September), strong low-level jet
- ! Series of weak upper-level impulses propagating into the Southeast.
- ! Hydrologically, the region's soil and surface storage (streams, lakes, and rivers) were near capacity. Antecedent soil moisture influences the partitioning of rainfall between runoff and infiltration.



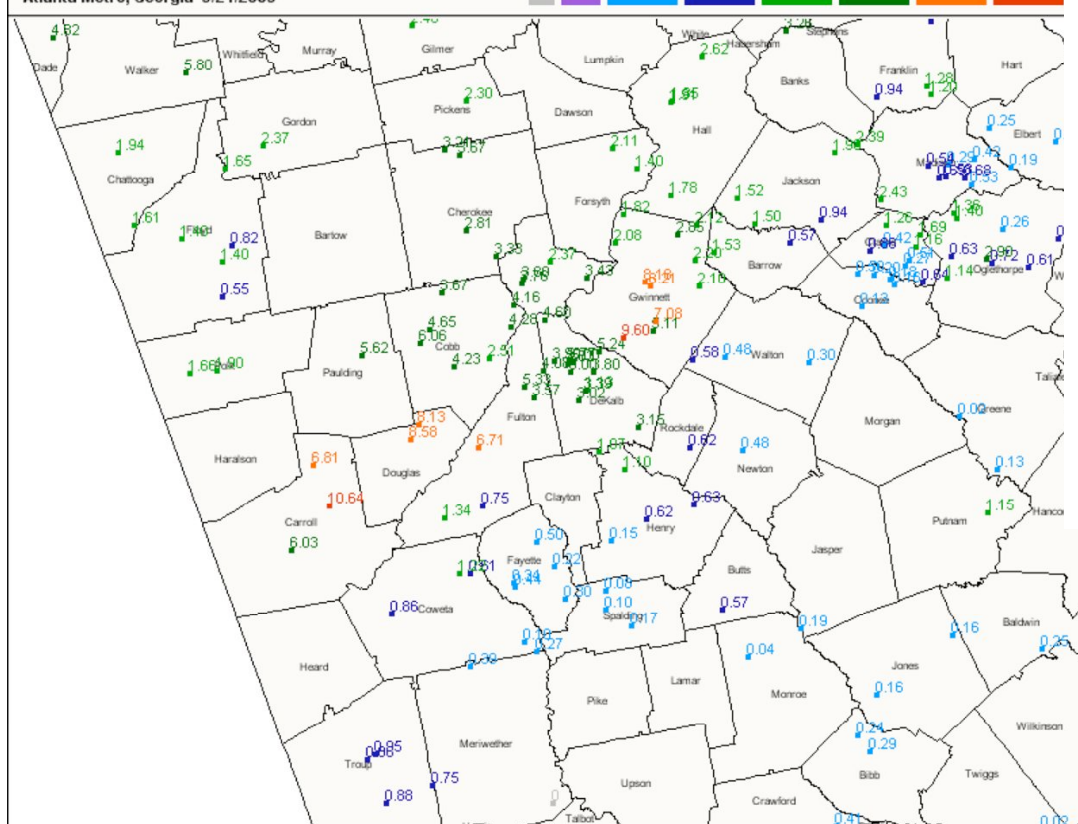
! This scenario set the stage for sustained, intense rainfall during 20-22 September to exceed an apparent “critical” threshold for catastrophic flooding.

Multiple Perspectives

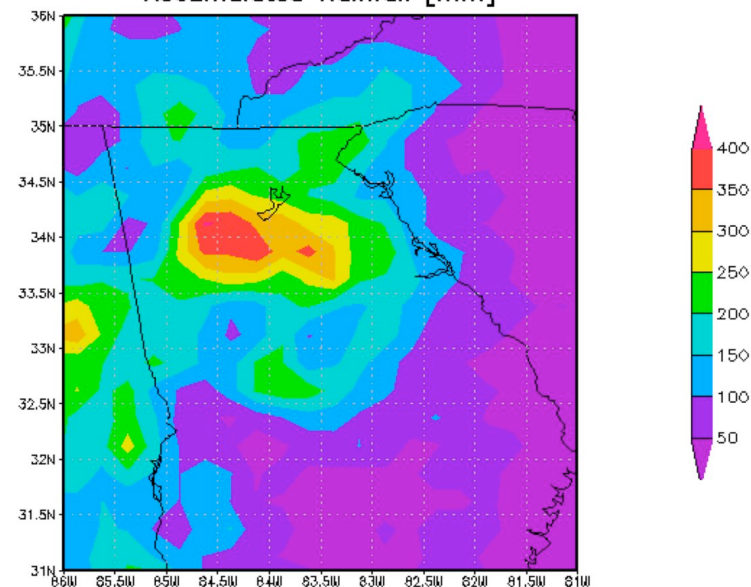
! Satellite

! CoCoRahs

Daily Precipitation (inches x.xx), for the 24 hour period ending ~7:00 am
 Atlanta Metro, Georgia 9/21/2009



TRMM TMPA-RT Daily 12Sep2009-23Sep2009
 Accumulated Rainfall [mm]

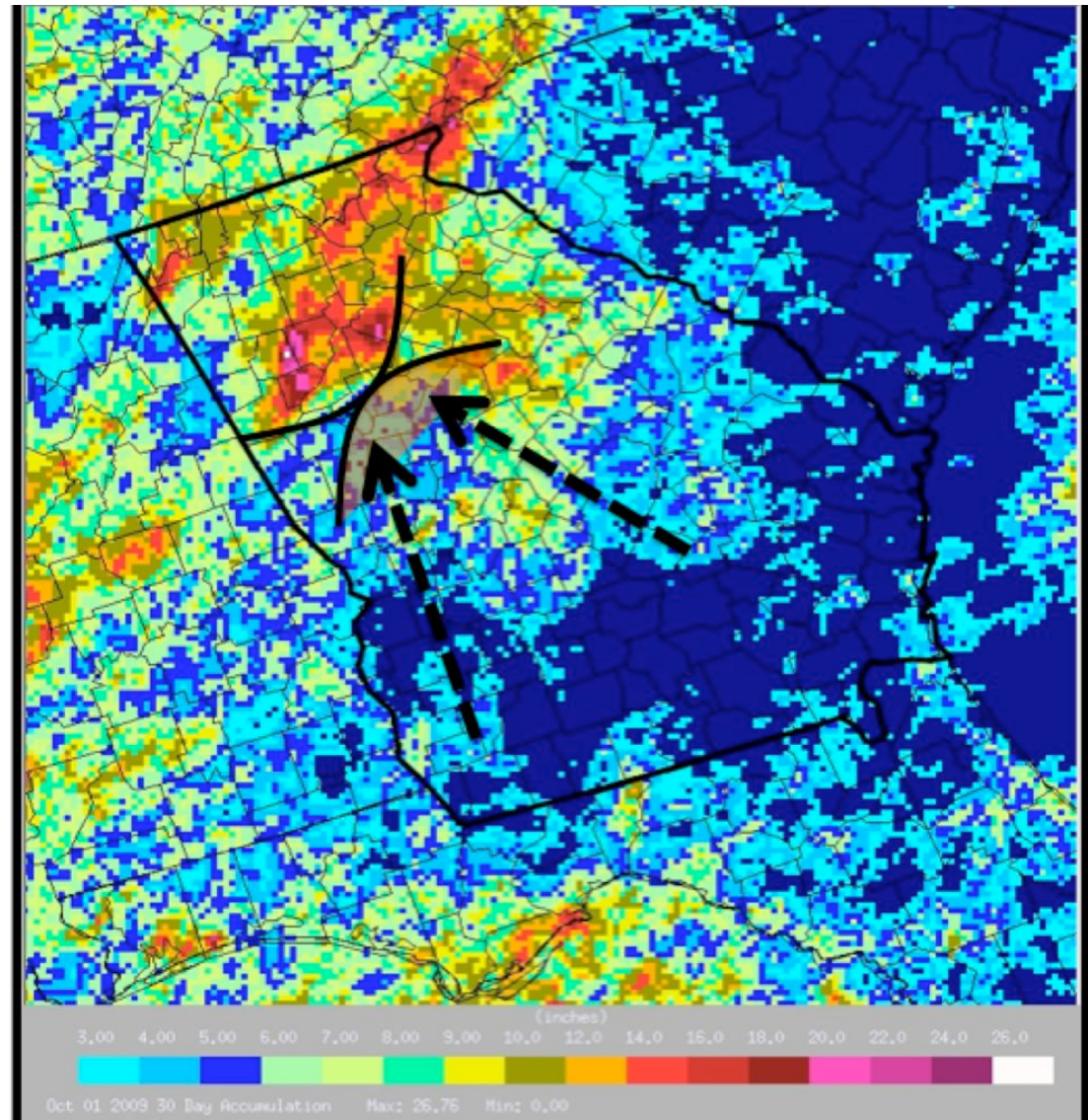


Generated by NASA's Giovanni (giovanni.gsfc.nasa.gov)

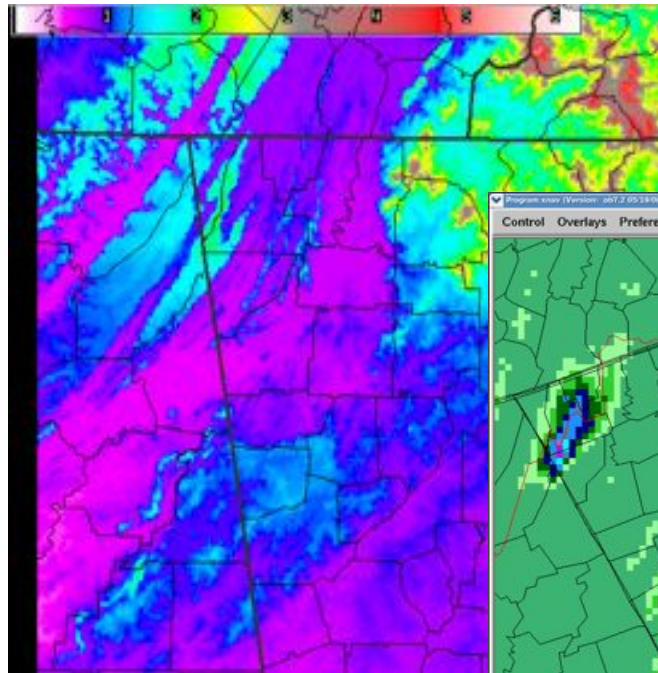
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Note preferred heavier
regions in mountains
and NW to NE
Atlanta Suburbs,
why?

- Orography/Training
- Boundaries
- Urban Effects

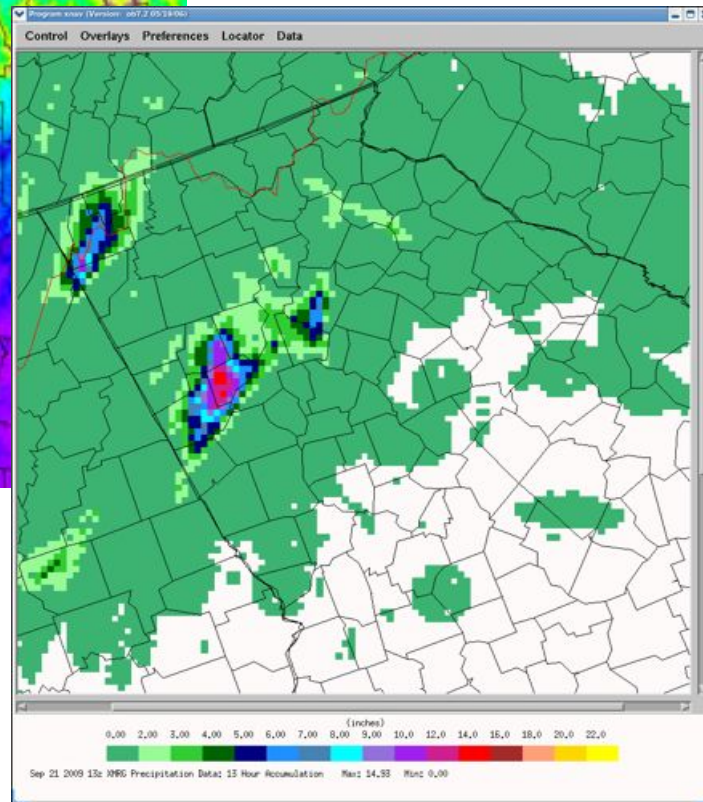


1. Orography

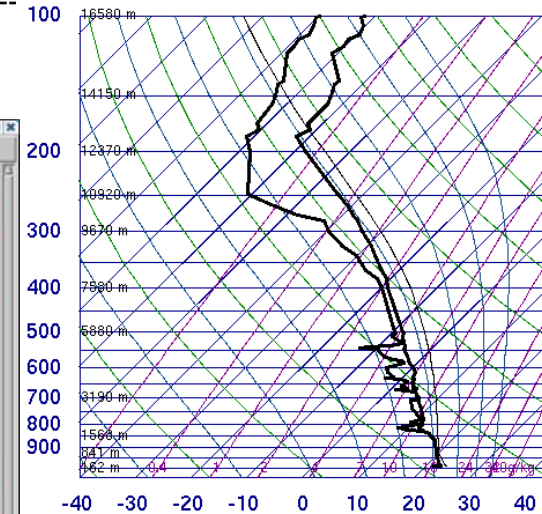


9/20 rainfall

Relief



72215 FFC Peachtree City



12Z 21 Sep 2009

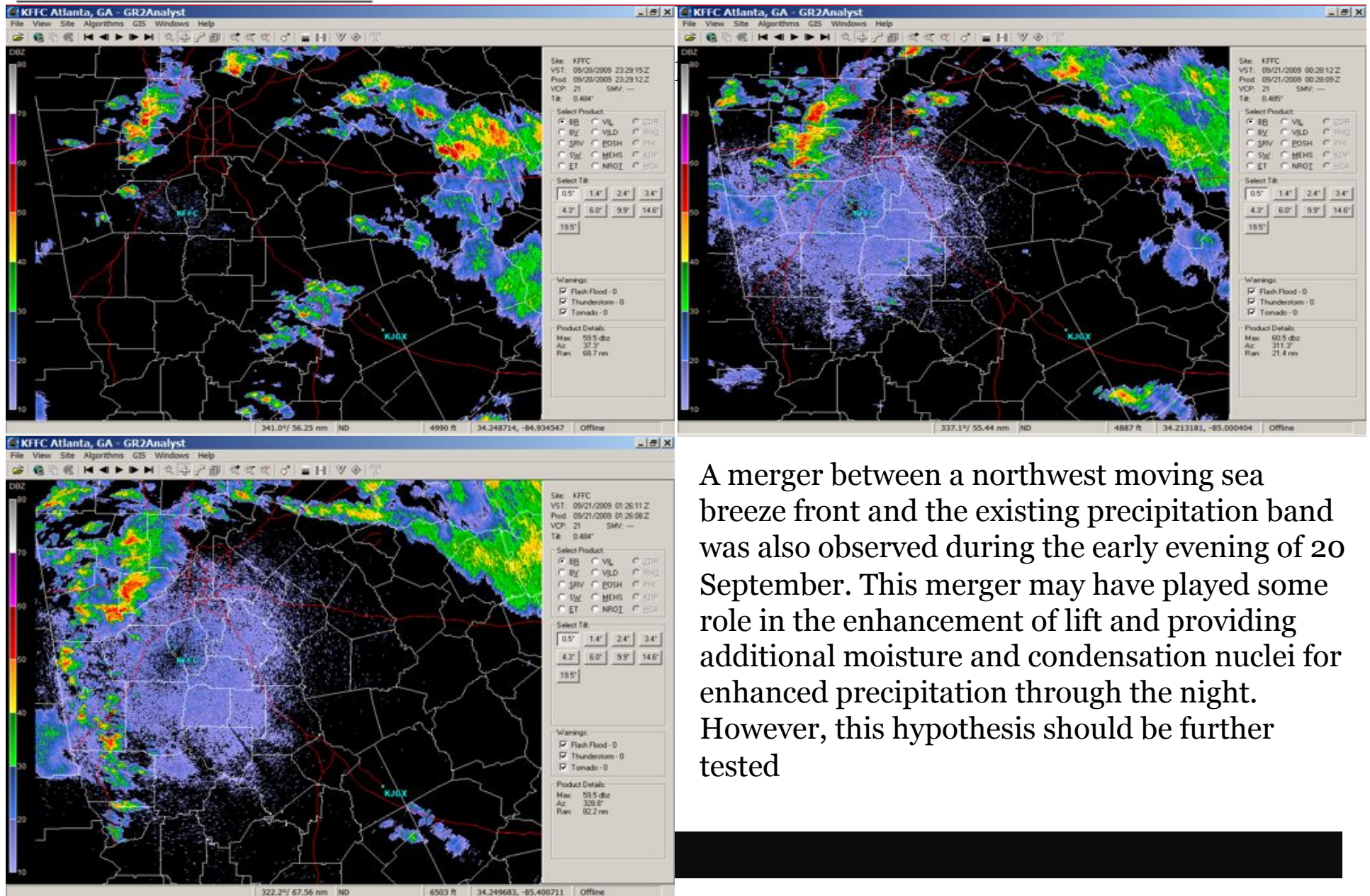
University of Wyoming

SE low-level flow, SW to W higher up—Good set-up for *training*.

SLAT	33.36
SLON	-84.56
SELV	244.0
SHOW	-1.70
LIFT	-3.87
LFTV	-4.19
SWET	314.5
KINX	38.70
CTOT	23.50
VTOT	23.50
TOTL	47.00
CAPE	1539.
CAPV	1648.
CINS	0.00
CINV	0.00
EGLV	178.4
EQTV	178.4
LFCT	958.5
LFCV	958.5
BRCH	43.92
BRCV	47.04
LCLT	294.4
LCLP	962.4
MLTH	297.7
MLMR	16.90
THCK	5718.
PWAT	52.41

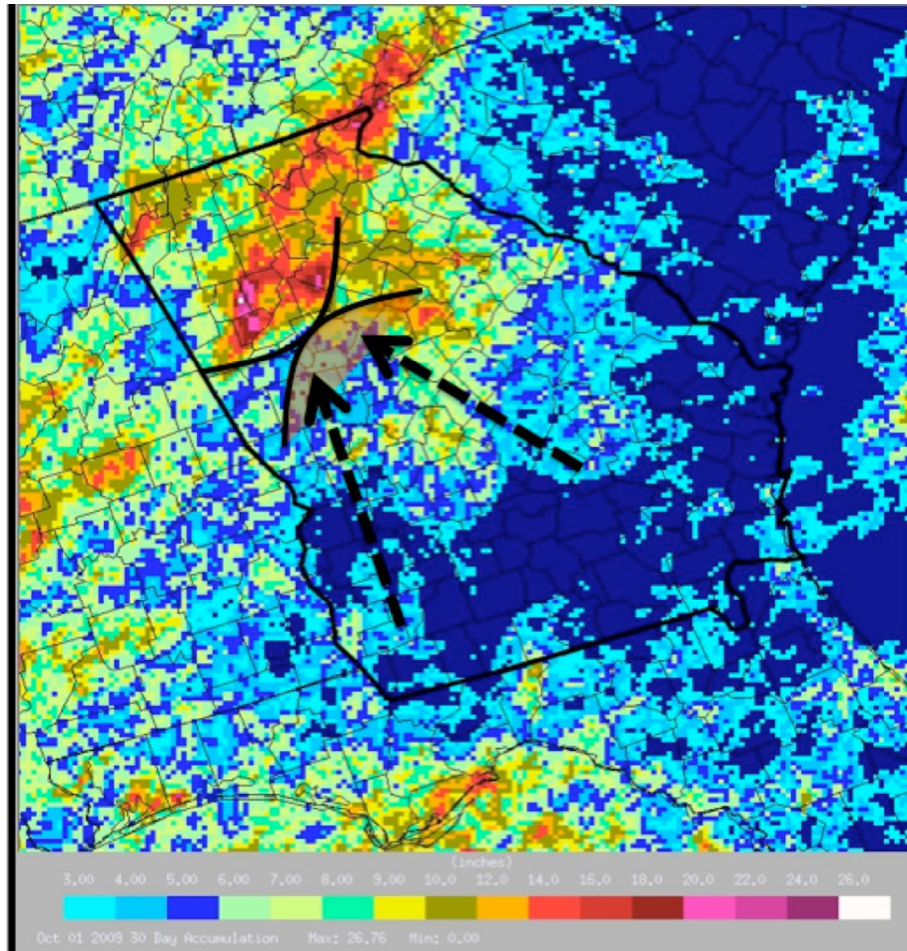
-Chappel (1986) describes this process as a near balance between cell movement and storm propagation and refers to these as “quasi-stationary convective events”. This process is observed in many environments, including tropical systems, warm fronts, and areas of orographic lift.

2. Sea Breeze/Boundary Interactions?



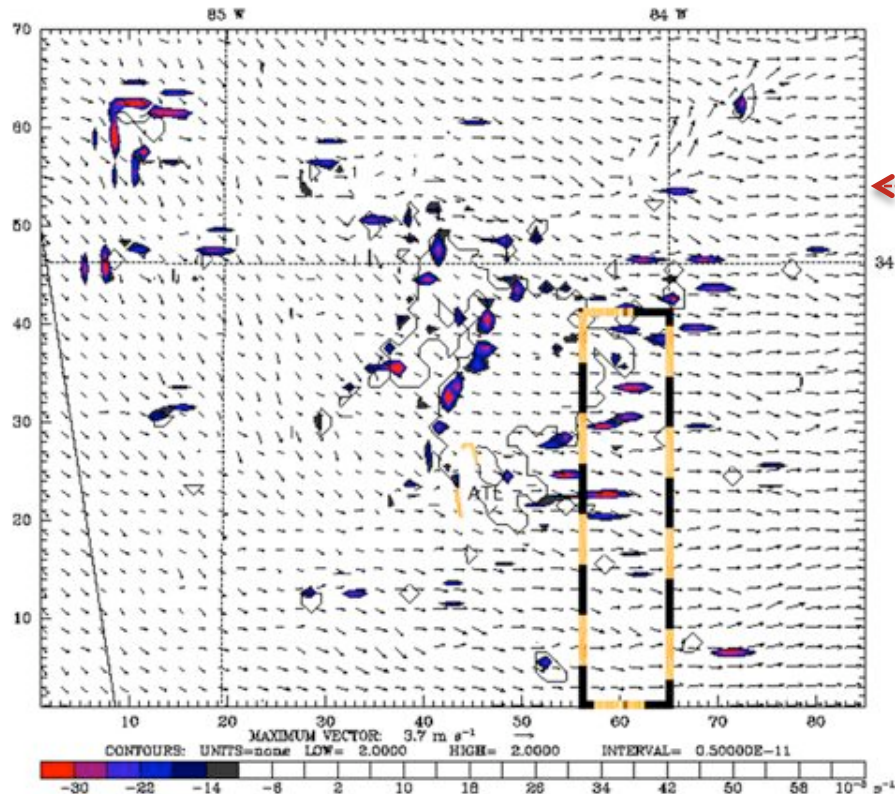
A merger between a northwest moving sea breeze front and the existing precipitation band was also observed during the early evening of 20 September. This merger may have played some role in the enhancement of lift and providing additional moisture and condensation nuclei for enhanced precipitation through the night. However, this hypothesis should be further tested

3. Urban Effects



- ! The flow regime places the regions of most intense metro ATL rainfall in the “downwind” region in the framework of Shepherd et al. 2002 (adapted from Metromex era). Orography alone may not explain the Gwinnett anomaly or other urban anomalies.
- ! Forecast models don’t represent land cover boundary conditions well at all.

3. Urban Effects



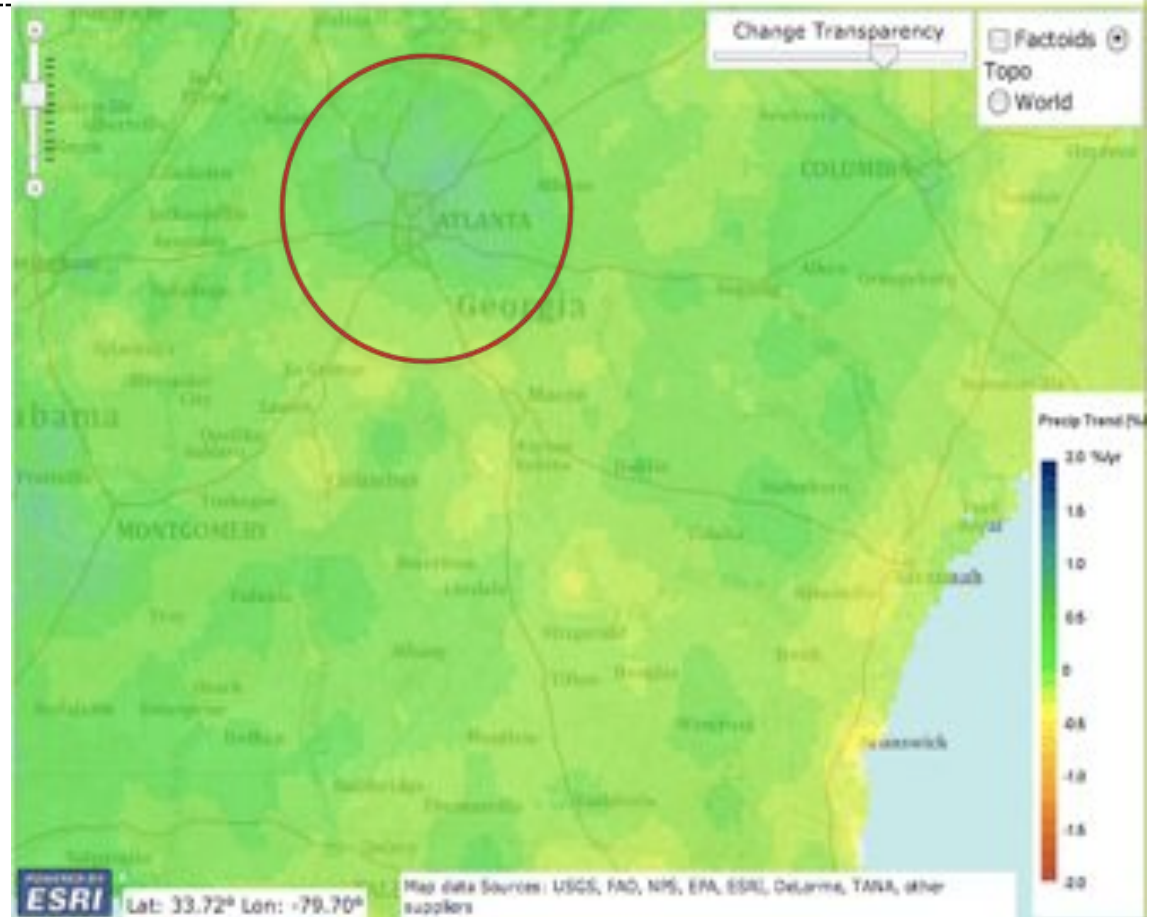
More speculative for this case: Shem and Shepherd (2008) and Niyogi et al. (2006) recently used modeling and radar-based observational studies to illustrate how *urban land cover* might enhance pre-existing convective storms. Shepherd et al. (2010) and Shem and Shepherd (2008) discuss the mechanisms for this urban enhancement (enhanced convergence, destabilization due to urban heat island warming, and increased sensible heat flux) for the city of Atlanta.

! More certain for this case: Reynolds et al. (2008) found that *impervious surfaces* in Houston distributed stormwater to conveyance systems with more volume over a shorter amount of time, which increases the risk of overwhelming the capacity of the system. It is likely that Atlanta experienced a similar response as what is described in Reynolds et al. (2008).

Concluding Thoughts

Change in Jun-Aug Precipitation 1951 - 2006

- ! The Atlanta floods were caused by *hydrometeorological* factors, BUT
- ! IPCC (2007)--frequency and severity of extreme hydroclimate events (e.g., droughts, floods) will likely increase in response to the acceleration in the water cycle.
- ! Groisman et al. (2004) argued that heavy and very heavy rainfall events have already increased in the 20th century, and Brommer et al. (2007) found that long duration rainfall events are becoming wetter.
- ! This timely analysis is relevant from the perspective of meteorological analysis as well as climate analysis.



!Trends in Summer N. Georgia Rainfall over past 50+ years (Shepherd 2010, forthcoming).

!ATL metro-greater trend, Why