



Extreme Rainfall in the Southeast U.S.



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Causes of Extreme Rainfall

Weather Scale

- Mid-latitude low pressure systems
- Slow moving or stalled fronts
- Tropical Storms or cyclones
- Stationary or training convective storms
- Sea breeze thunderstorms and outflow boundaries

Climate Scale

- Rainfall accumulated over weeks or months
- Difficult to predict in summer season
- Significant impacts from El Nino in the winter
- Long-term changes in extreme rainfall?



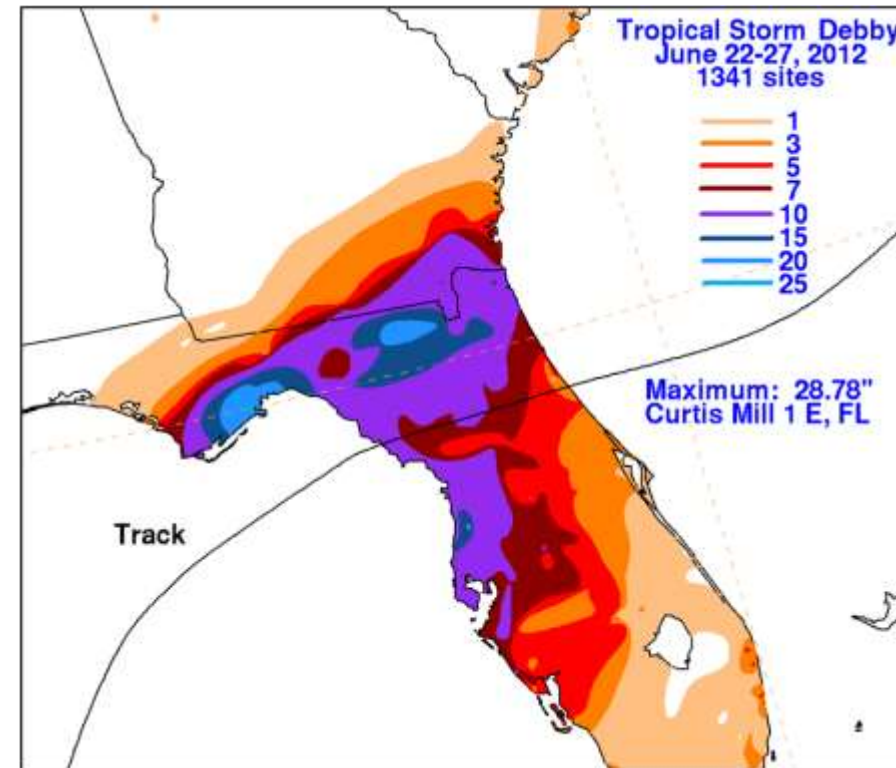
Recent Extreme Rainfall Events

Weather Related

- Tropical Storm Debby 2012
- Panhandle April 2014 floods
- Colorado floods 2013
- South Carolina Sept. 2015

Climate Related

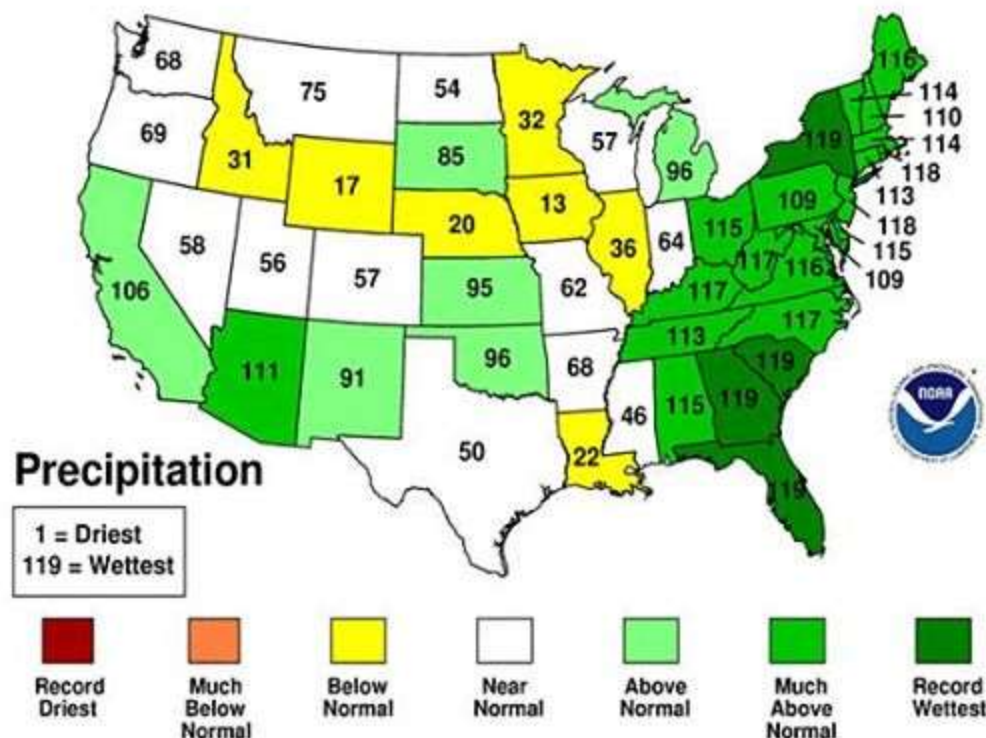
- Winter 1998
- Fall 2009
- Summer 2013
- Spring 2014
- Texas/Oklahoma Floods May 2015
- Tampa Area Rainfall July 2015



2013 Wettest Summer Ever?

June-August 2013 Statewide Ranks

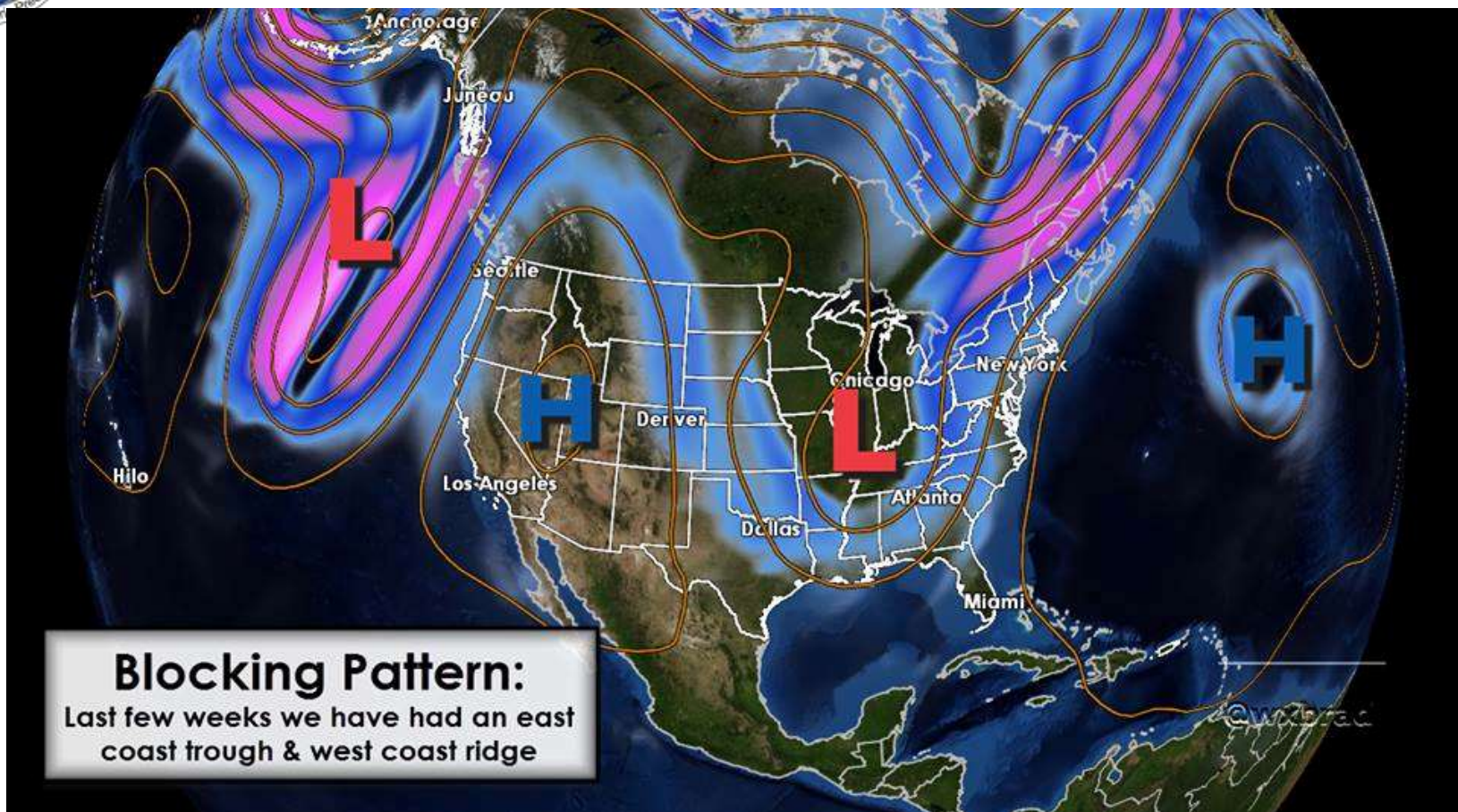
National Climatic Data Center/NESDIS/NOAA



- Wettest July on record for Florida, Georgia and Alabama 4th wettest
- Wettest May-July on record for South Carolina, Florida 2nd wettest and Georgia 3rd
- Wettest Feb-July on record for Georgia and South Carolina
- Wettest June-August for entire Southeast Region

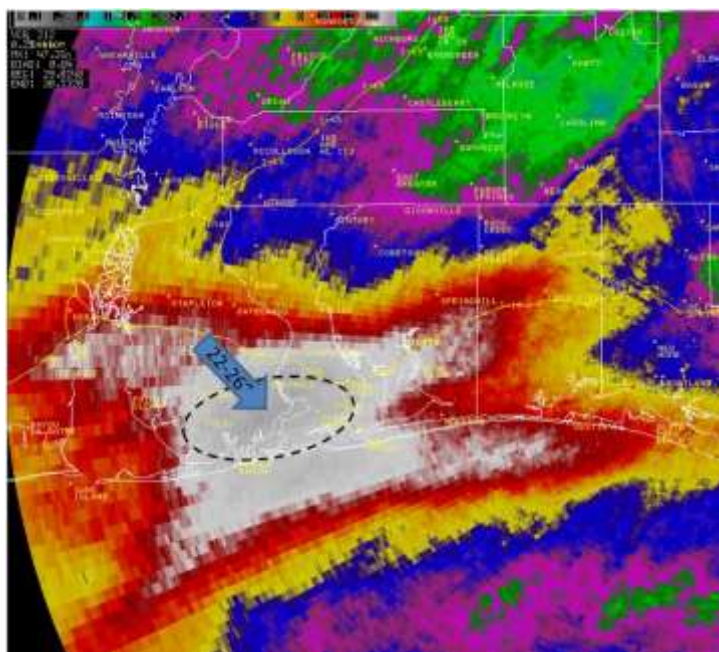
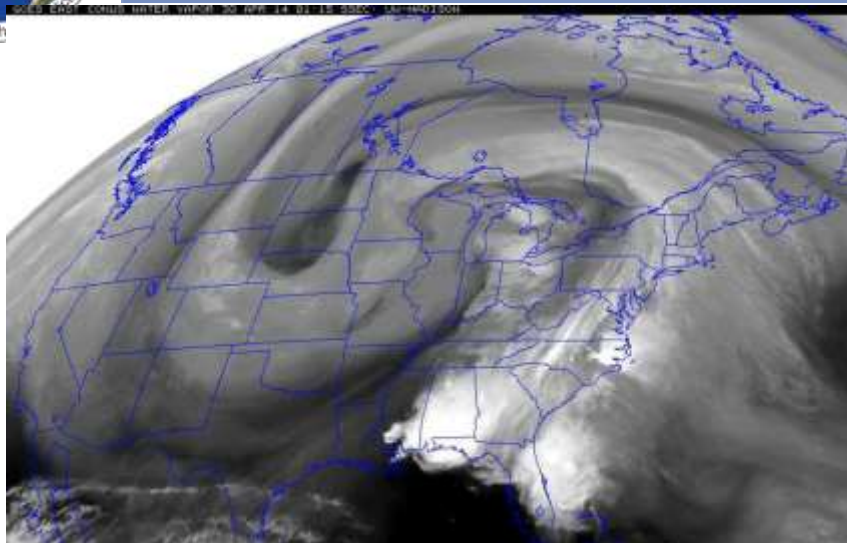


Blocking Pattern



June 6-7, 9-10; June 29-July 7, July 22-29, Aug. 16-20

NW Florida April Flood 2014



Station Number	Station Name	Daily Precip Sum in.	Multi-Day Precip in.	Total Precip in. ▾
AL-BW-35	Orange Beach 1.3 E	19.00	4.67	23.67
AL-BW-45	Silverhill 5.0 SW	21.80		21.80
AL-BW-9	Foley 0.5 ESE	20.76		20.76
AL-BW-27	Orange Beach 2.1 NE	20.53		20.53
AL-BW-3	Daphne 1.2 NNW	16.47		16.47
AL-BW-32	Fairhope 3.1 NNW	16.13		16.13
AL-BW-40	Fairhope 1.5 WSW	15.51		15.51
AL-BW-65	Silverhill 0.9 SSE	15.47		15.47
AL-BW-68	Spanish Fort 1.6 W	15.45		15.45
AL-BW-13	Fairhope 3.7 NNW	14.29		14.29
AL-BW-4	Daphne 0.4 SW	14.23		14.23
AL-BW-1	Fairhope 2.3 N	14.12		14.12
AL-BW-60	Daphne 1.5 SSW	13.98		13.98
AL-BW-58	Spanish Fort 1.2 NE	13.83		13.83
AL-BW-36	Daphne 4.2 NE	13.81		13.81
AL-BW-26	Loxley 0.4 SSW	13.78		13.78
AL-BW-8	Foley 7.4 SW	13.47		13.47
AL-BW-41	Fairhope 2.3 E	13.44		13.44
AL-BW-31	Foley 2.0 SSW	13.17		13.17
AL-BW-20	Summerdale 4.3 WSW	13.03		13.03
AL-BW-53	Elberta 3.1 SSW	12.67		12.67
AL-BW-30	Fairhope 3.5 E	11.54		11.54
AL-BW-59	Bay Minette 10.9 N	5.98		5.98

FL-ES-21	Pensacola 9.2 NW	19.56		19.56
FL-ES-4	Gonzalez 2.5 NNW	15.43		15.43
FL-ES-15	Gonzalez 2.1 E	13.22		13.22
FL-ES-1	Pensacola 2.7 N	12.00		12.00
FL-ES-10	Pensacola 3.8 N	12.00		12.00

*Pensacola record calendar day rainfall – 15.55 inches

NW Florida April Flood



Spring 2014 Rainfall Anomalies

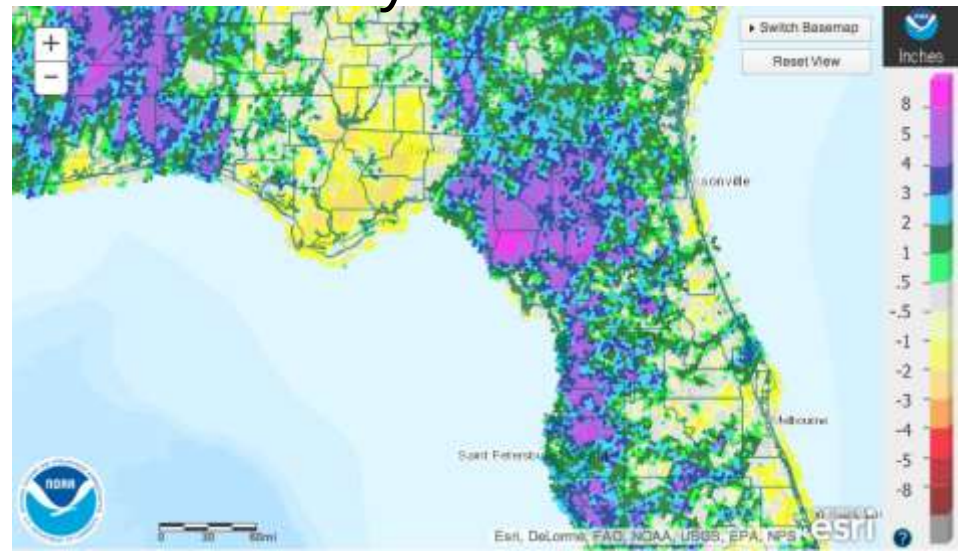
April



March



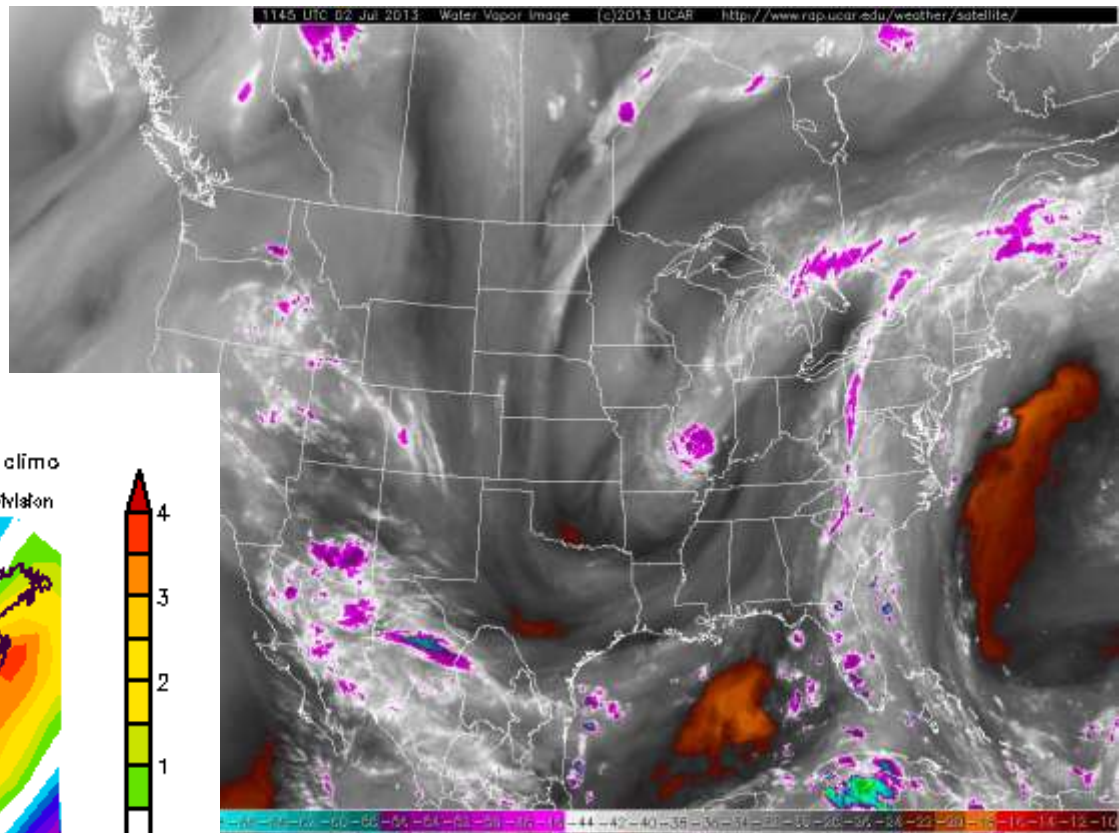
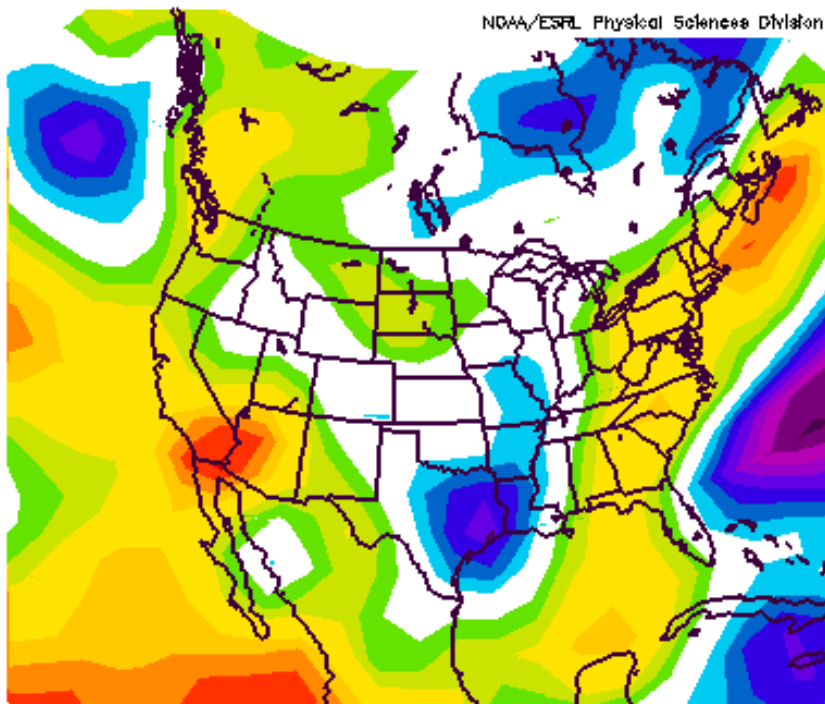
May



Moisture Anomalies

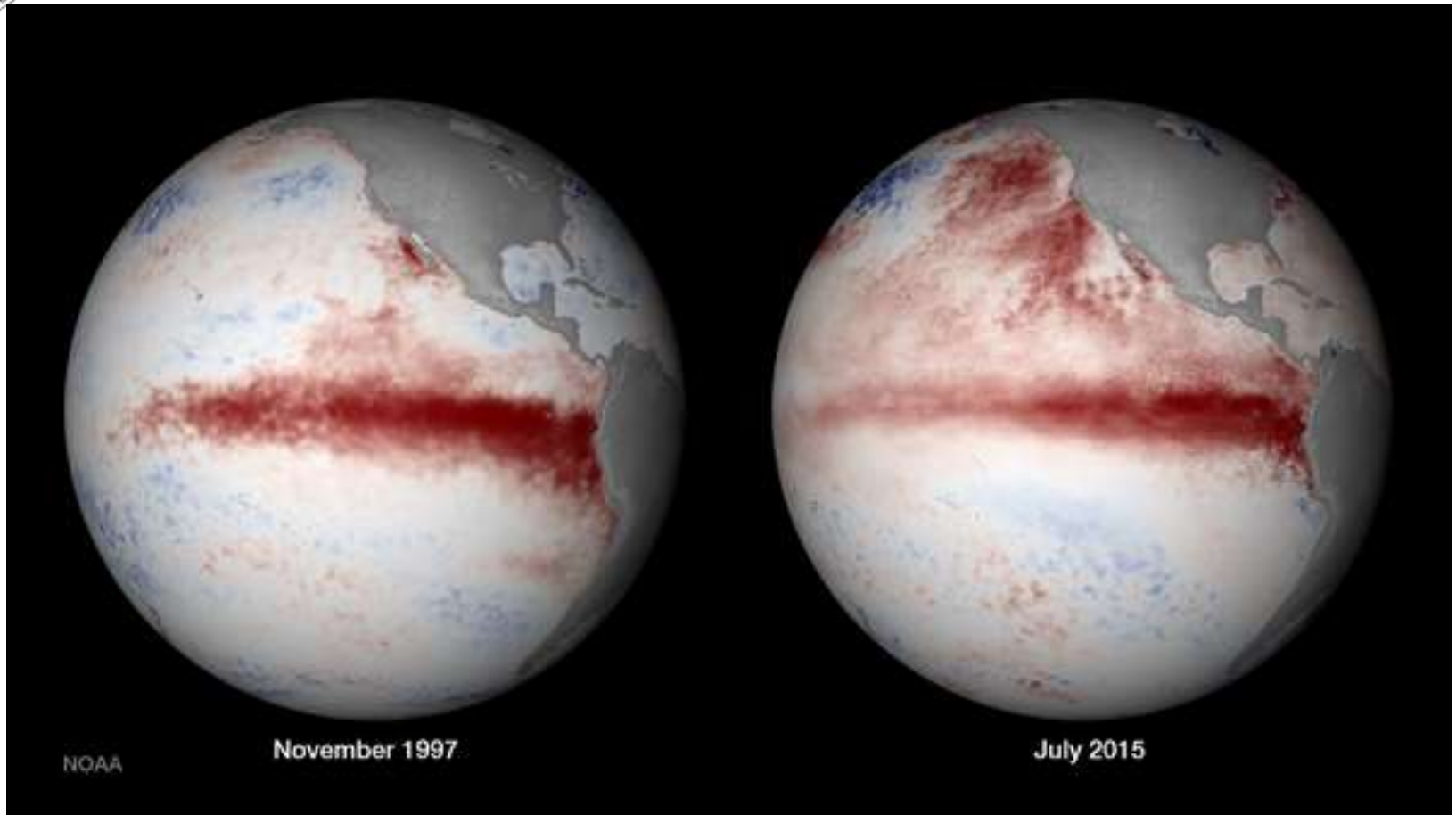
Precipitable Water Anomalies (JJA)

NCEP/NCAR Reanalysis
Surface Precipitable Water (kg/m^2) Composite Anomaly 1981–2010 climo
NOAA/ESRL Physical Sciences Division



Water Vapor Image (7/02)

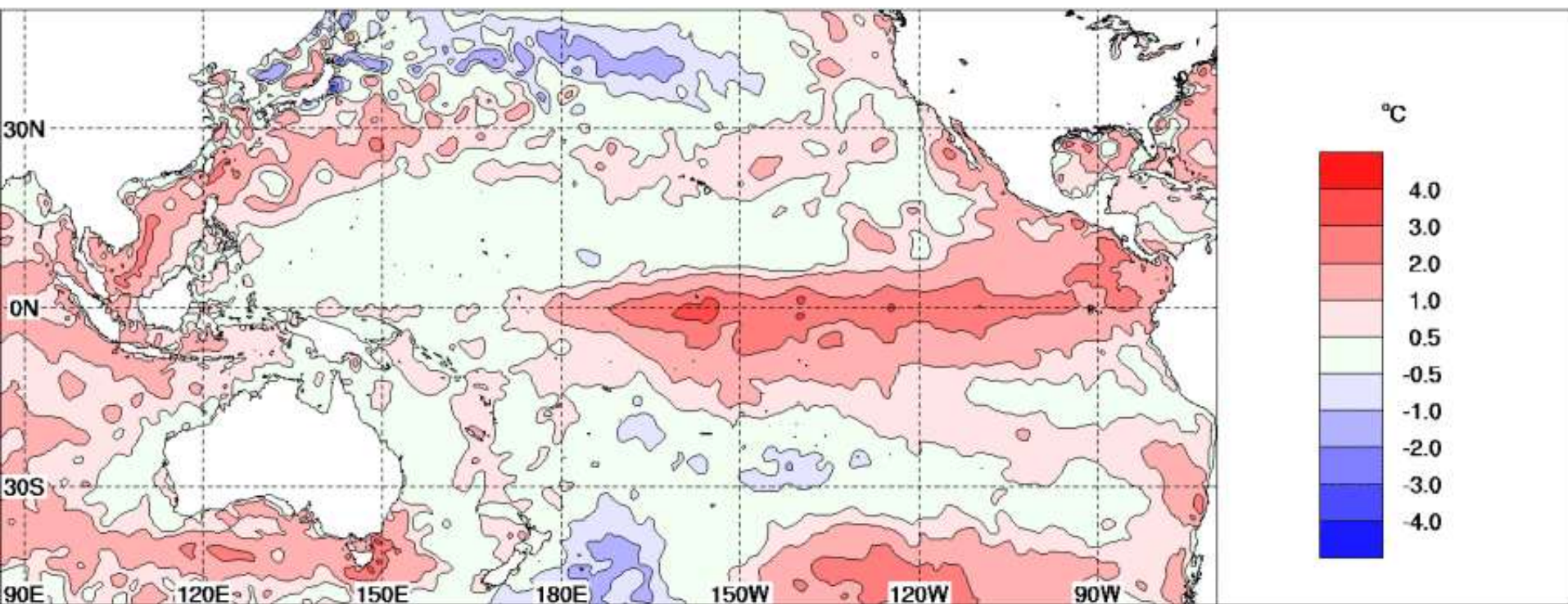
Strong El Nino Currently in Place



Current El Nino has the potential to rival the super events of 1982/1983 and 1997/1998

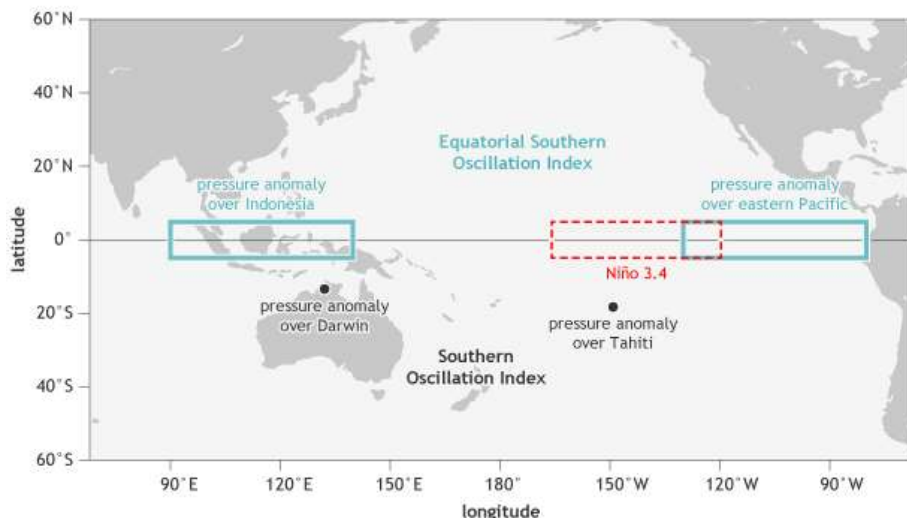
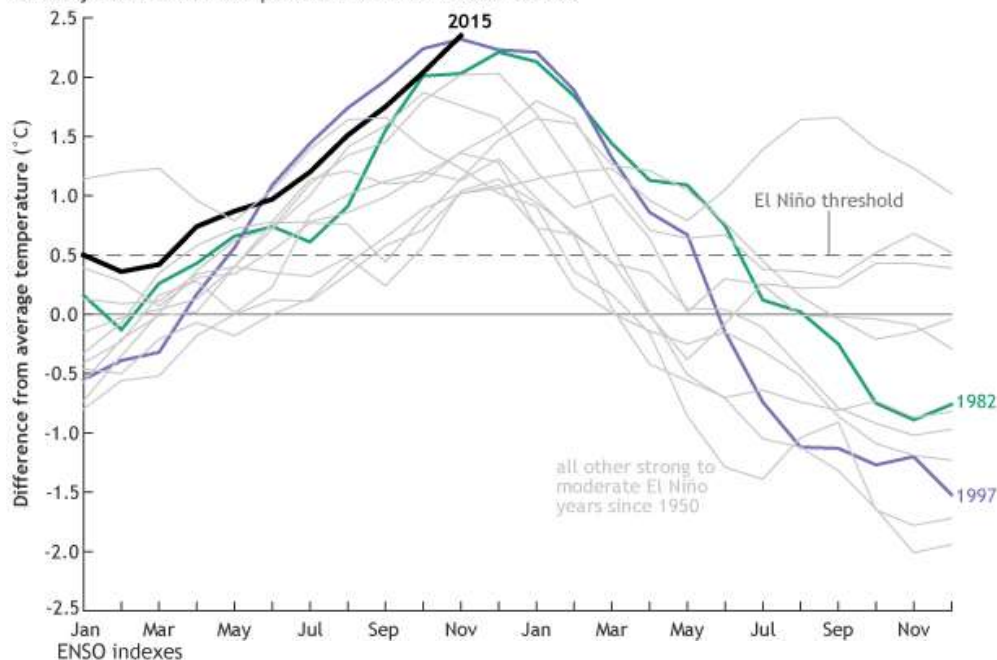
Current SST Anomalies

SSTA 1.0X1.0 NMOC OCEAN ANOMALIES (C) 20160101 20160131



Strongest El Nino this Century?

Monthly sea surface temperature Niño 3.4 Index Values



- SST's slightly higher than previous record values from 1997
- Coupled ocean-atmosphere phenomenon, atmosphere and impacts important
- In same category as 1982/83 and 1997/98

El Niño and Tropical Cyclones



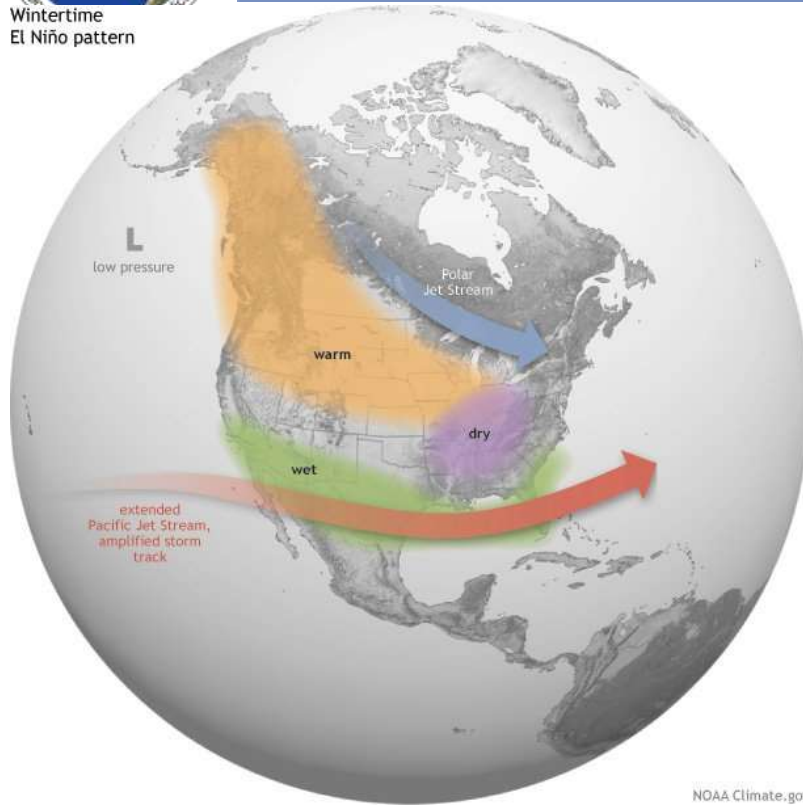
Atlantic Summary

- Seasonal forecasts from NOAA and CSU among the lowest ever.
- Number of storms near average, ACE and landfalls well below.
- 10-year streak without major U.S. hurricane or any Florida landfall continues

North Pacific Summary

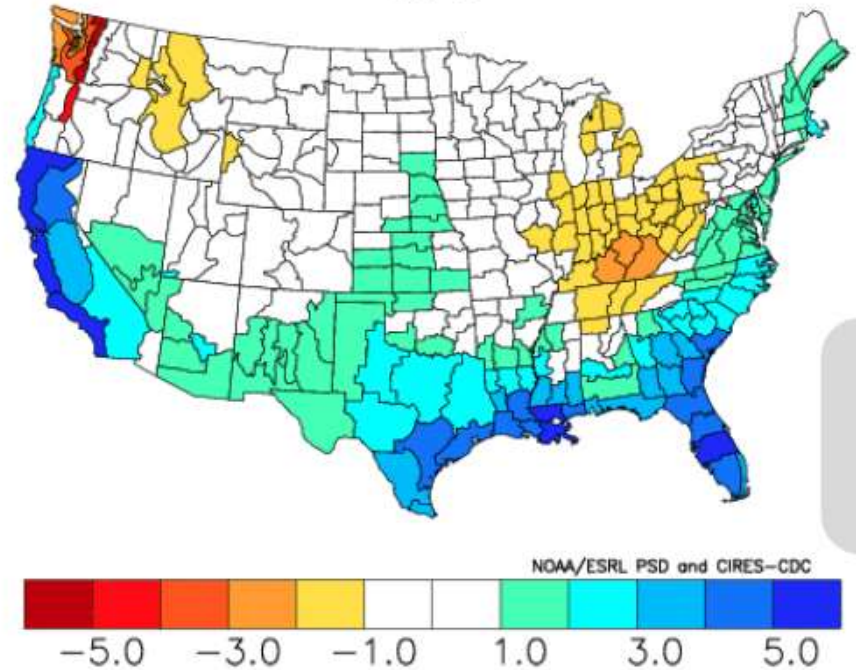
- 23 Category 4-5 hurricanes in the North Pacific in 2015
- ACE at or near record levels for all regions of the N. Pacific

Cold Season Precipitation Patterns



NOAA Climate.gov

Composite Precipitation Anomalies (inches)
 Versus 1971–2000 Longterm Average
 Nov to Mar 1982–83, 1972–73, 1957–58, 1965–66, 1986–87, 1991–92, 1968–69, 1997–98
 2002–03,

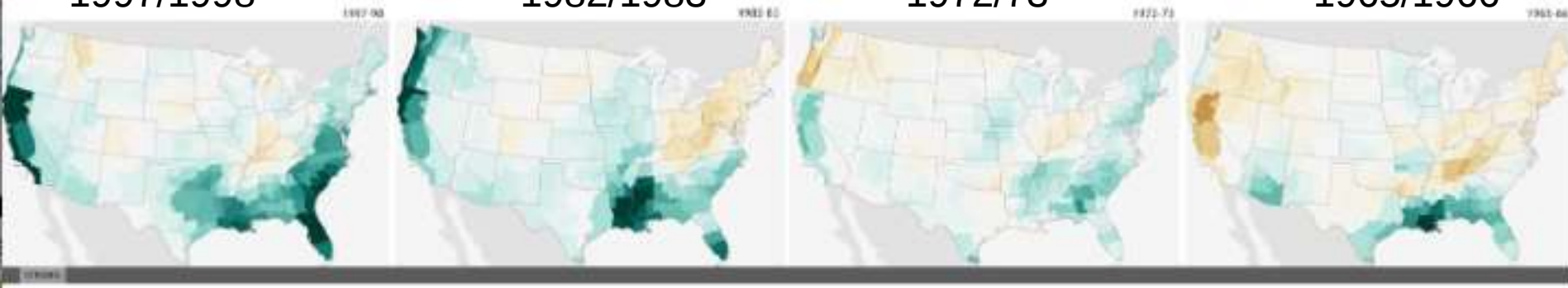


1997/1998

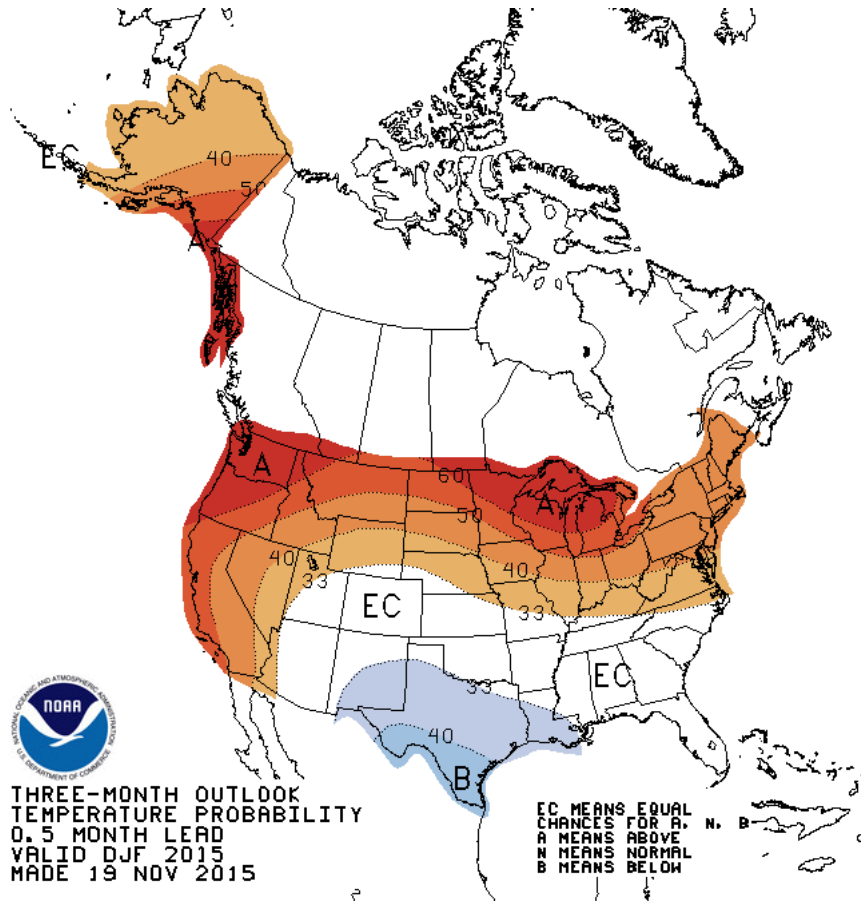
1982/1983

1972/73

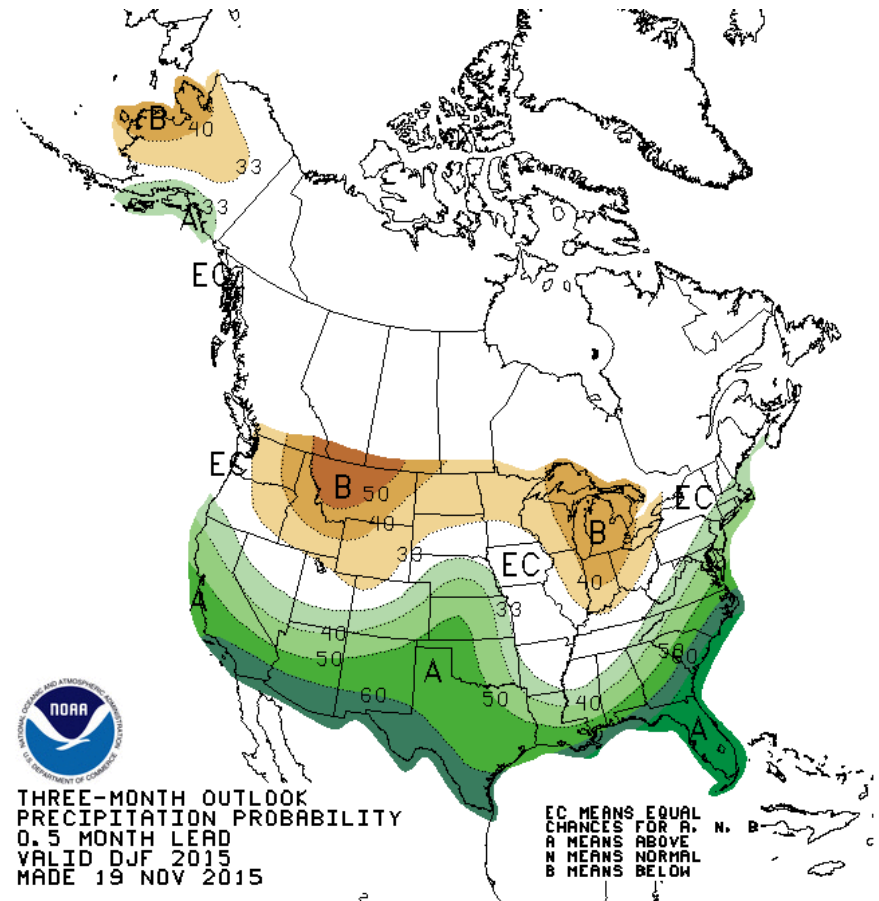
1965/1966



NOAA Winter Forecast



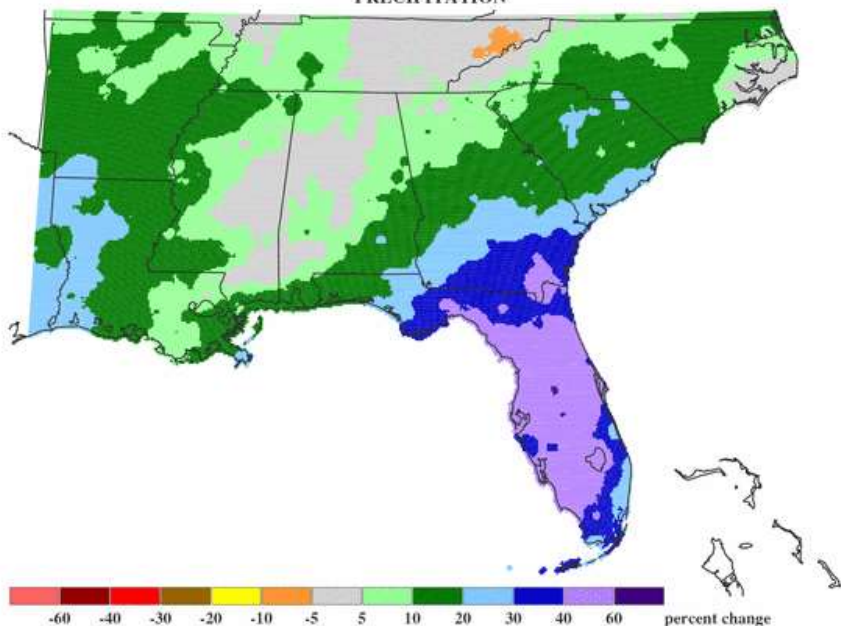
Temperature



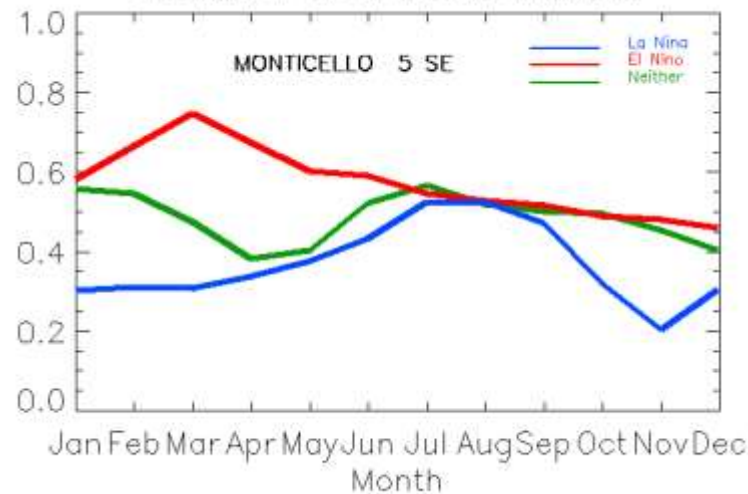
Precipitation

El Nino and Heavy Rain

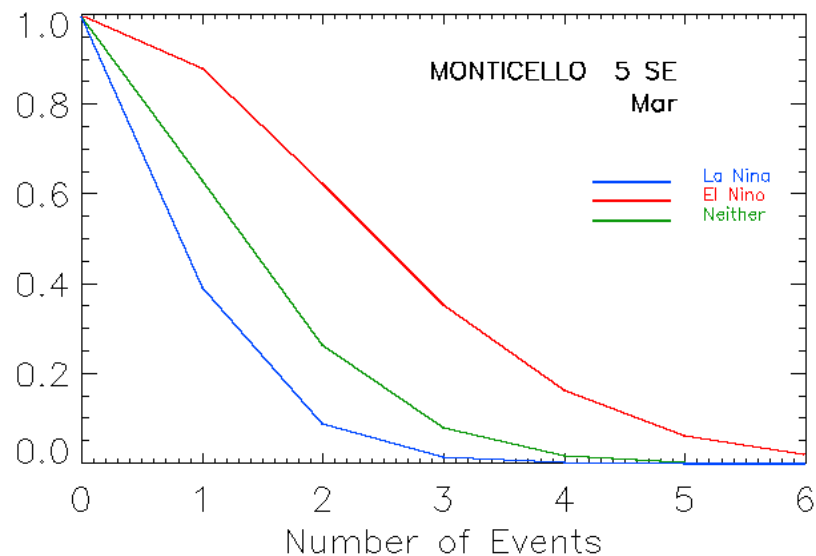
JANUARY
EL NINO vs. NEUTRAL
PRECIPITATION



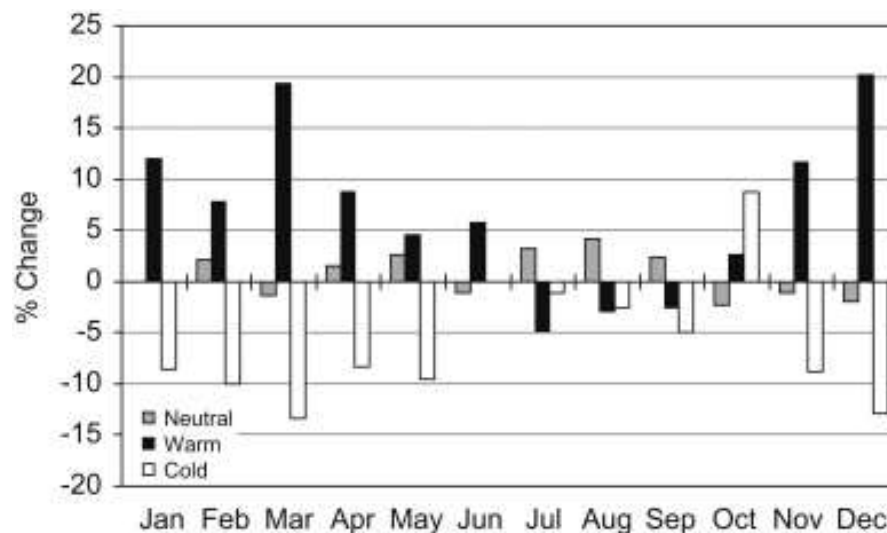
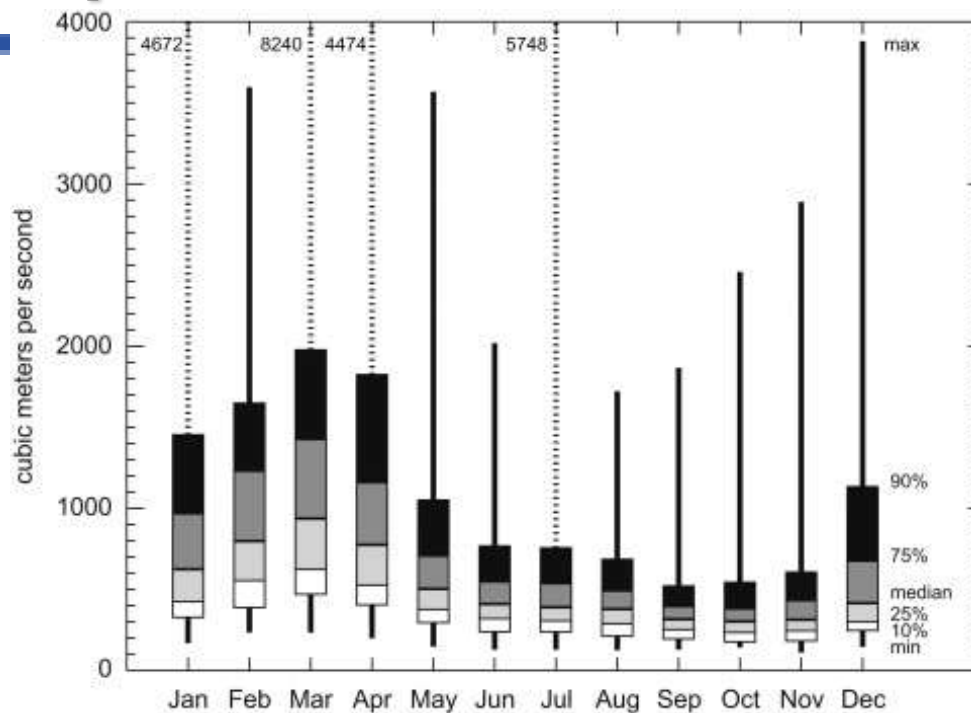
Probability of One or More Two-Inch Rains



Probabilities of Two-Inch or Greater Rain

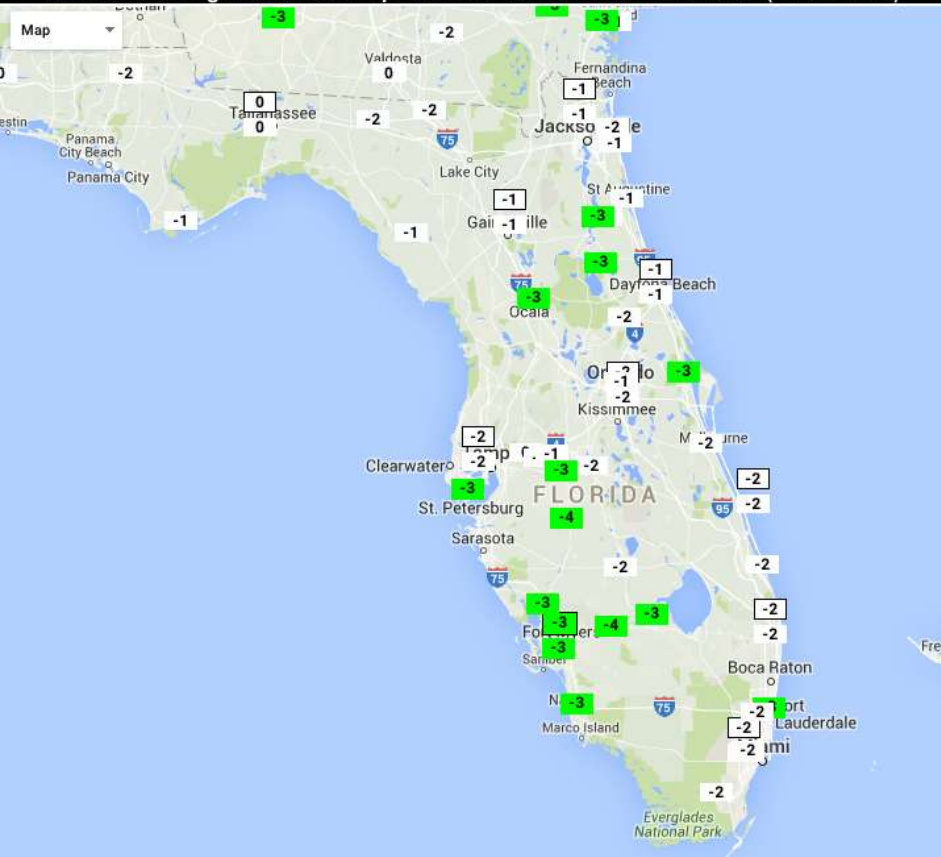


Apalachicola River Flows



2016 Temperature and Rainfall

Observed Average Maximum Temperature for Jan 1 2016 to Feb 29 2016 (334 stations)



Observed Total Precipitation for Jan 1 2016 to Feb 29 2016 (334 stations)





Remembering 1998



- State record winter (Nov. – Mar.) rainfall, 33 inches over south-central Florida
- Lake Okeechobee rises to 18.6' (currently 16.14' and rising).
- \$100 million in crop damage from flooding, 75% loss of strawberry crop

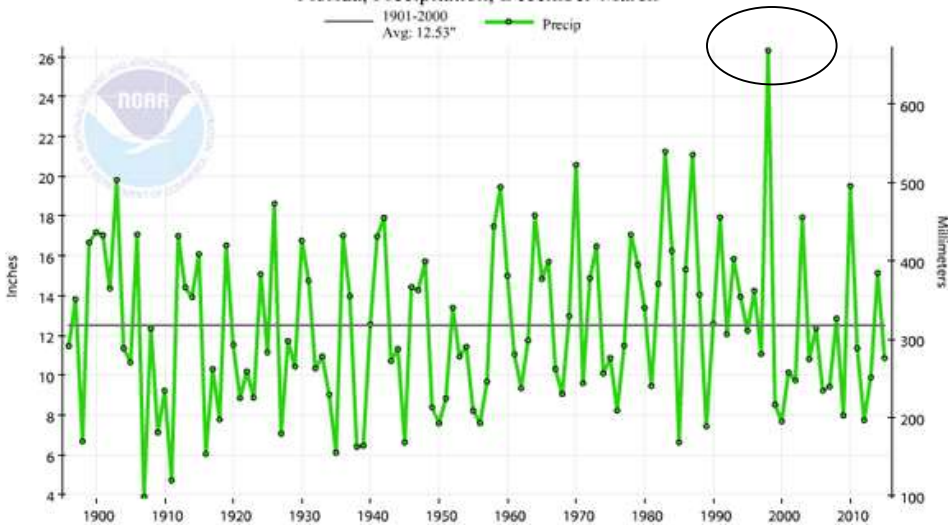


- Deadliest tornado outbreak, killing 42 and injuring 350
- Tourism and occupancy rates dipped sharply
- Worst wildfire season on record, half-million acres burned, \$620 million in losses

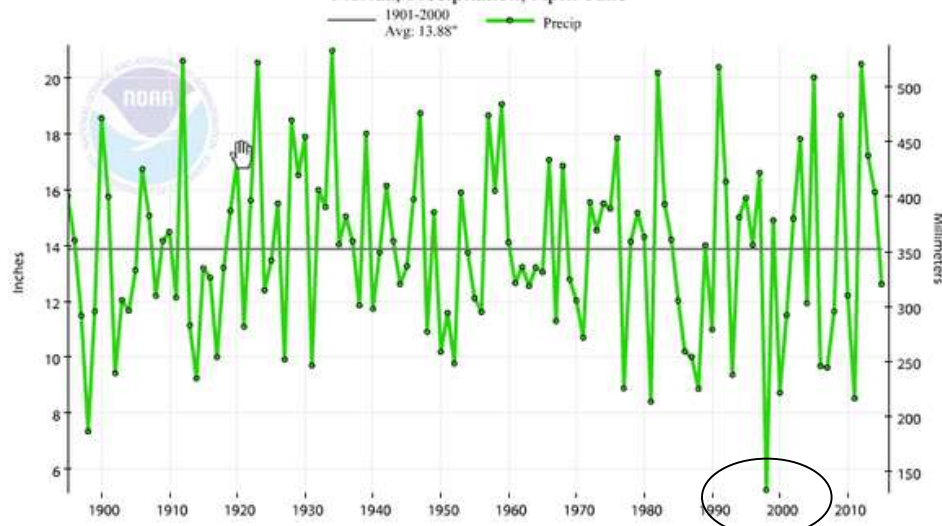


Will 2016 in Florida Repeat 1998?

Florida, Precipitation, December-March



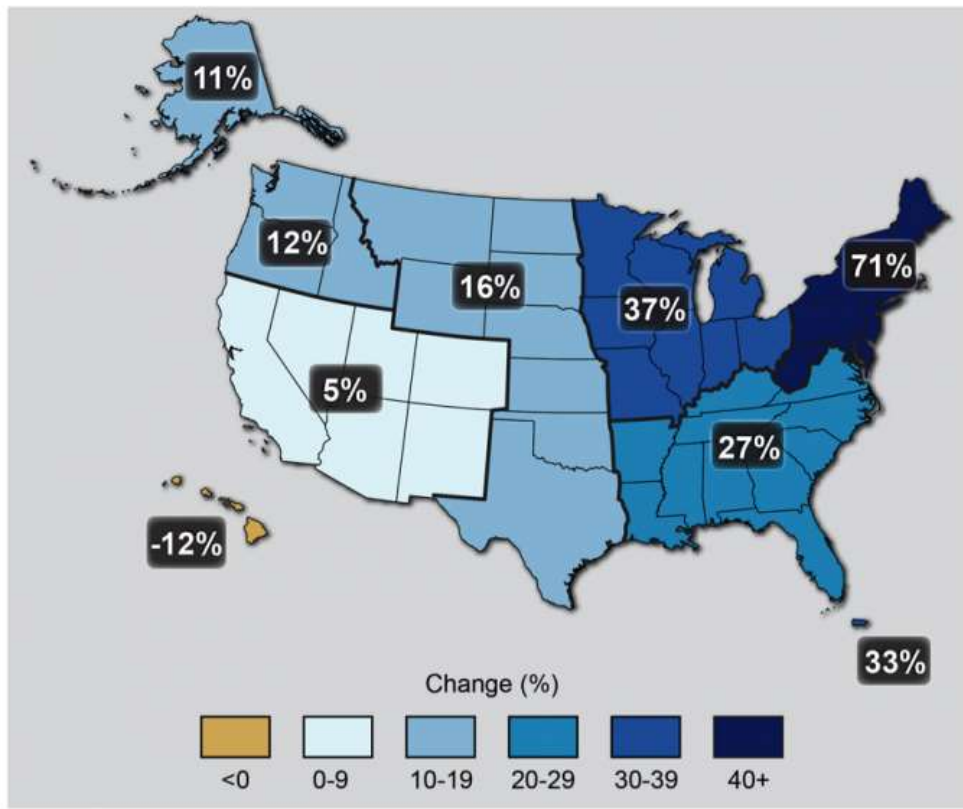
Florida, Precipitation, April-June



- Super El Nino of 1998 brought record winter rainfall to Florida
- April-June brought record dryness
- Over half million acres burned in worst wildfire season in memory
- In April and May, Pacific Ocean had unprecedented rapid transition from El Nino to La Nina, contributing to the changing weather patterns
- Similar transition unlikely, but Pacific conditions should be monitored closely as spring approaches

2014 National Climate Assessment

Observed Change in Very Heavy Precipitation

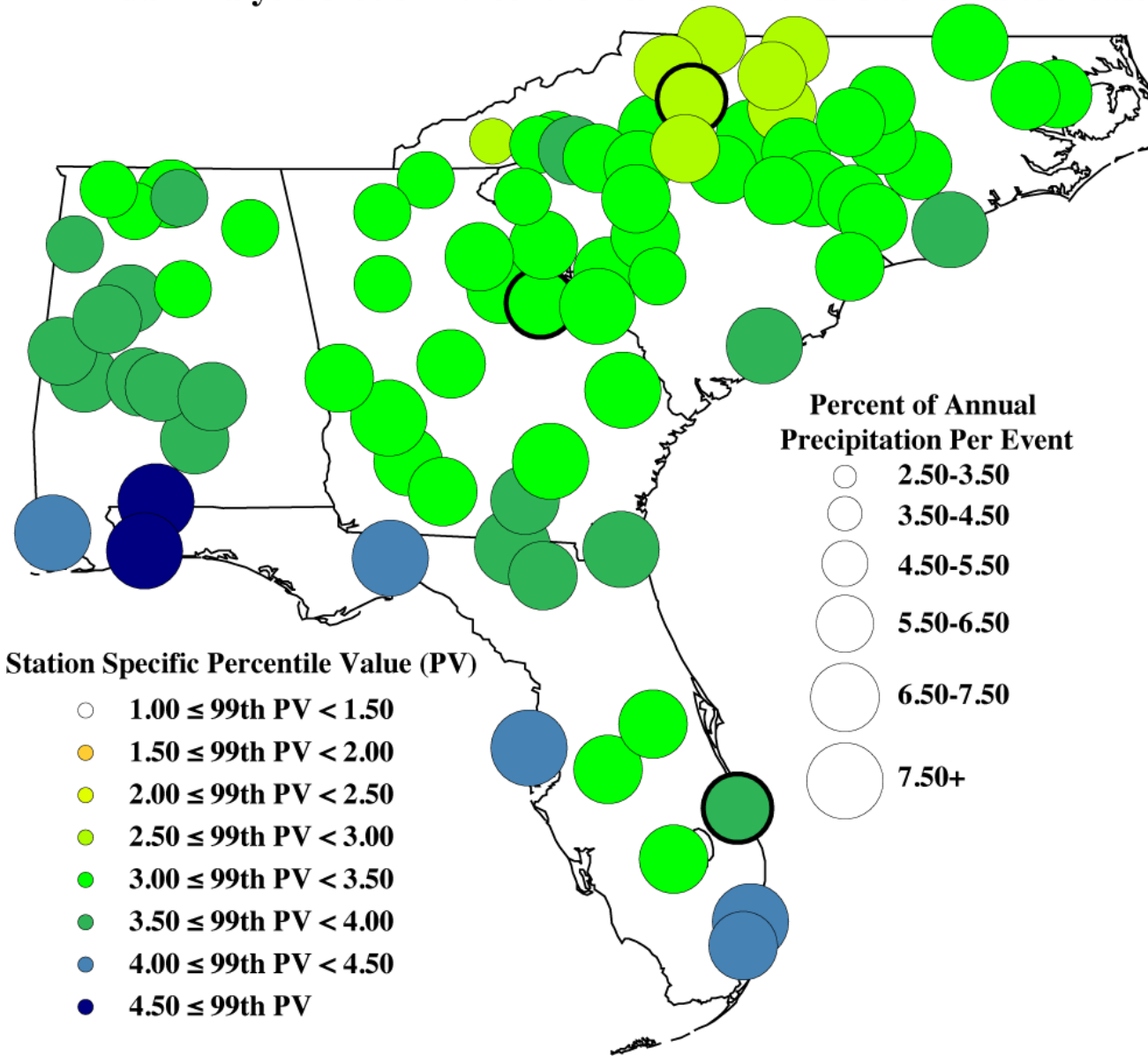


- Very heavy precipitation is defined at 99th percentile
- Use of one, annual-based number
- States, “recent trends towards increased heavy precipitation events will continue...even where total precipitation is expected to decrease”

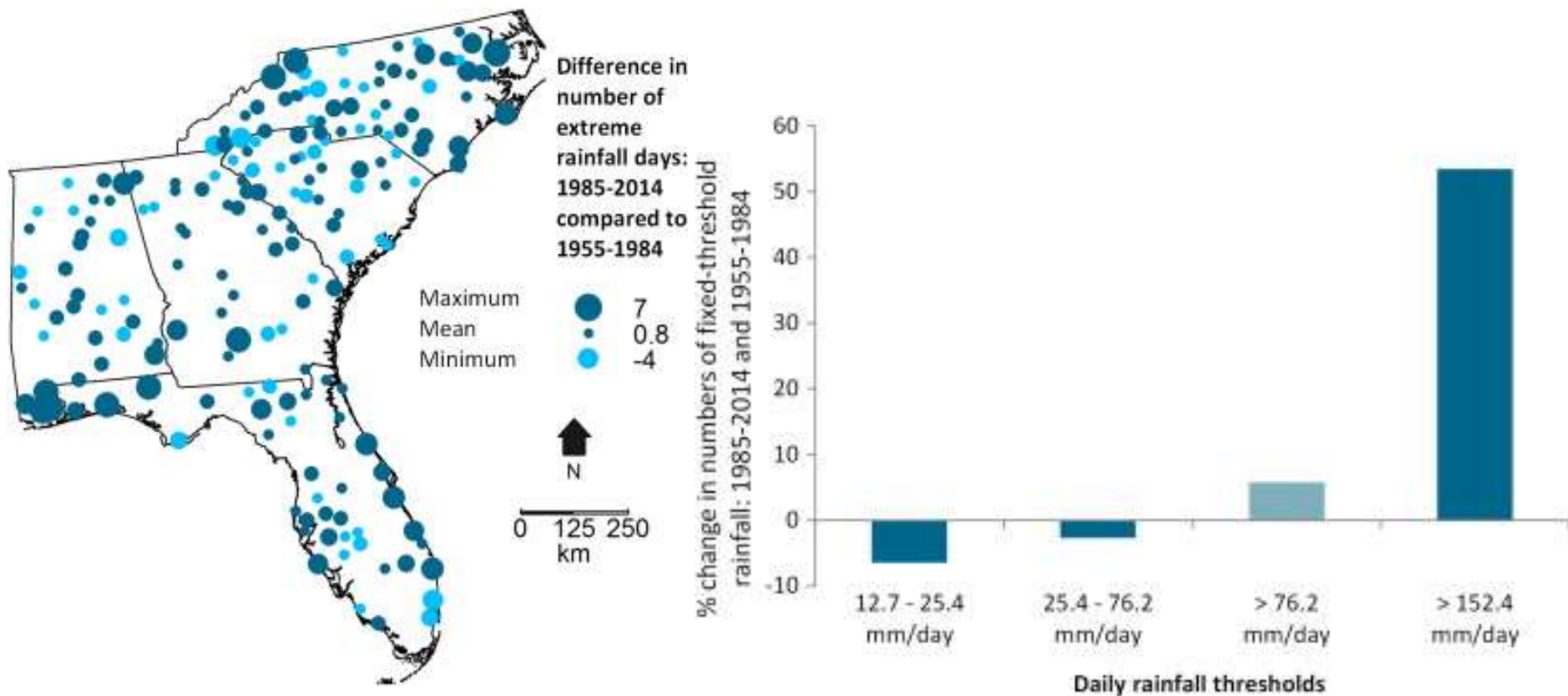
Figure Source: 2014 National Climate Assessment, updated from Karl et al 2009

Spatial Plots

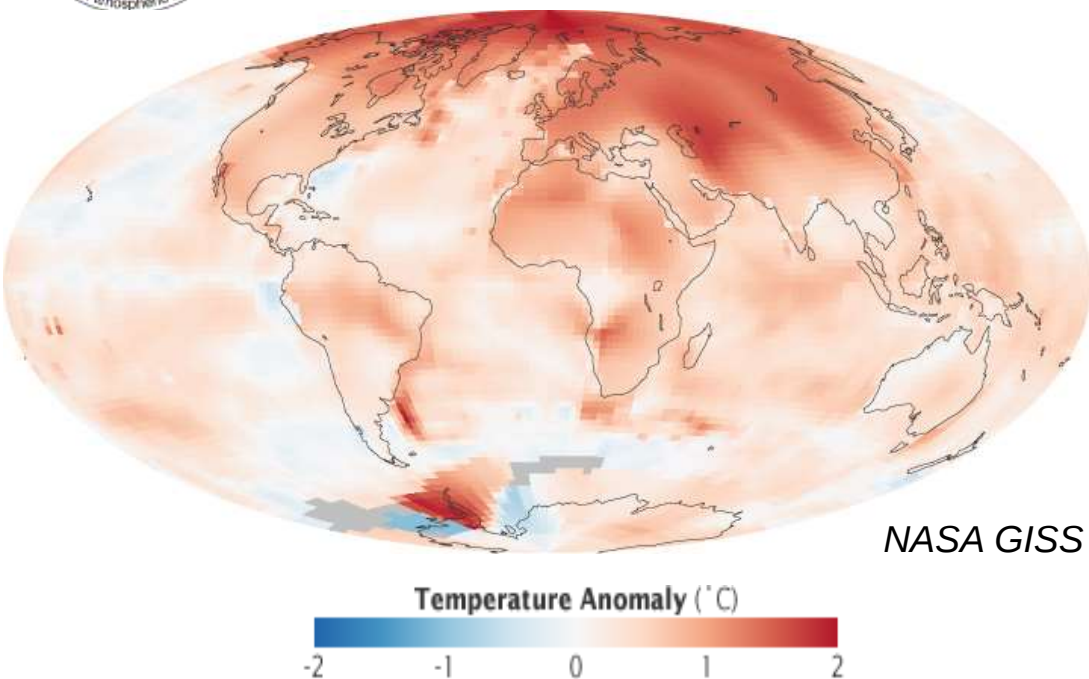
Annual Analysis of 99th Percentile Rainfall Events Over the Southeast



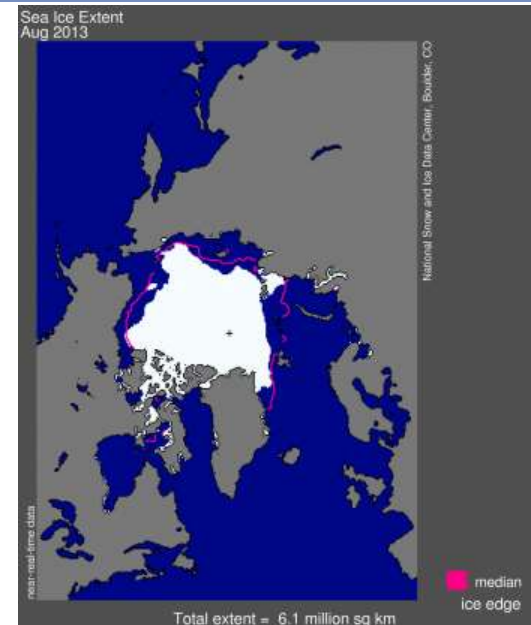
Changes in Rainfall Intensity



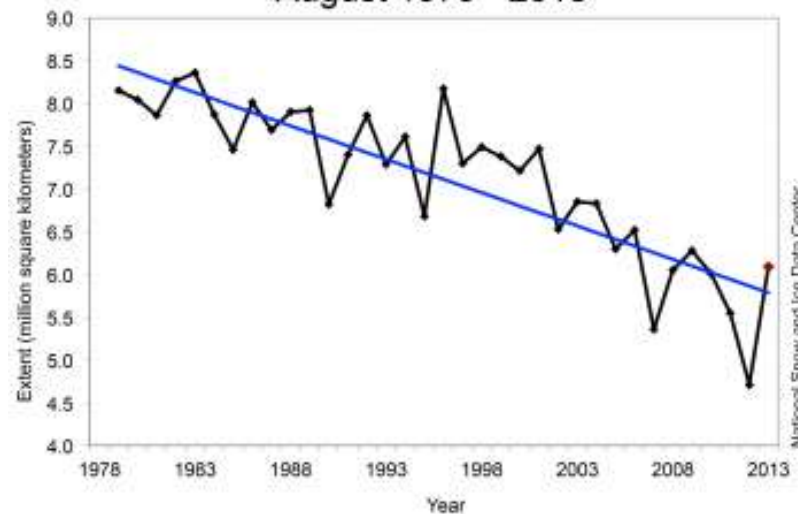
Arctic Amplification



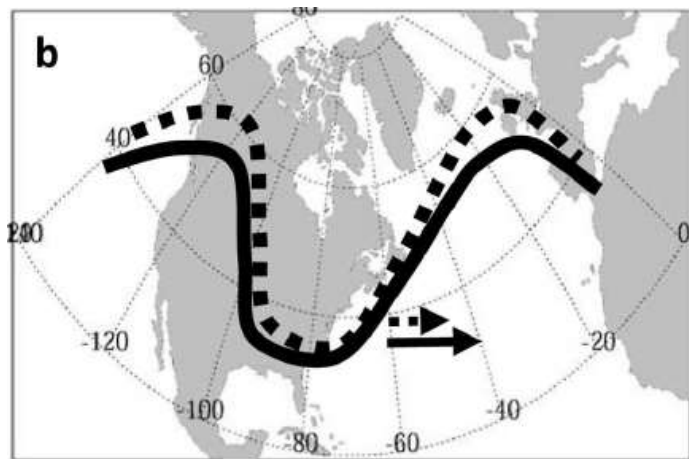
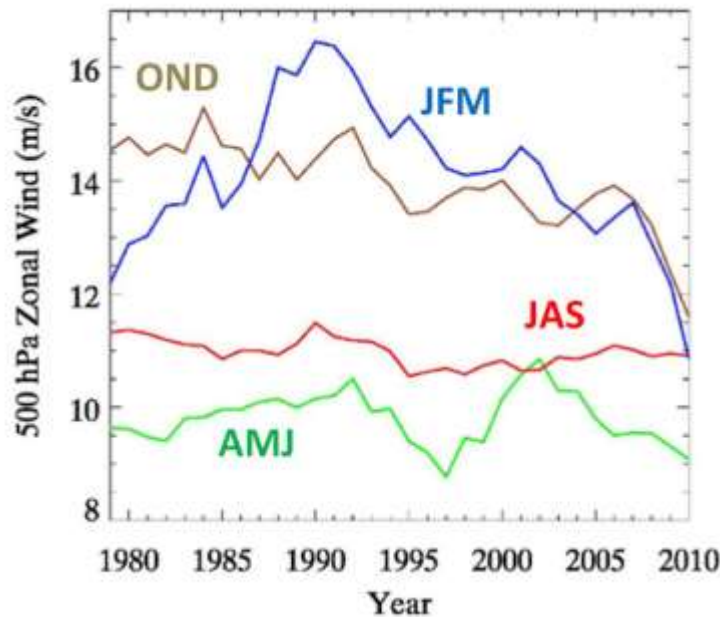
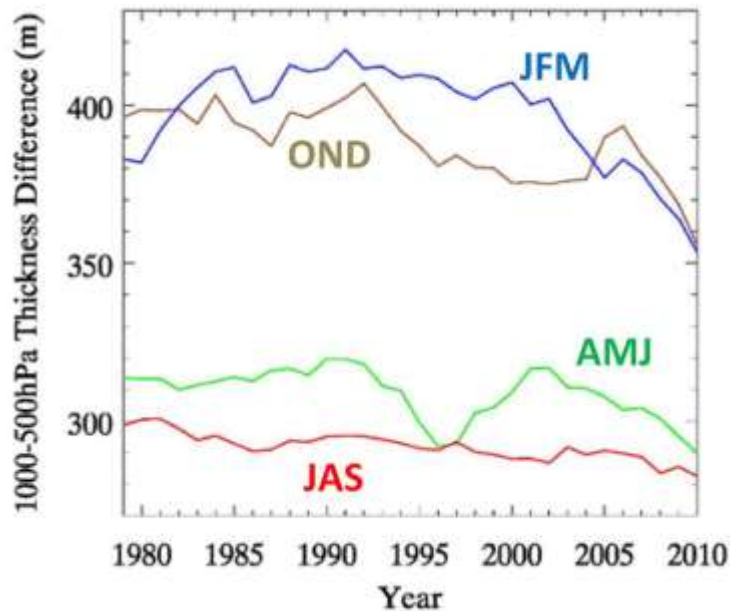
- Arctic and high latitudes have warmed 2 to 3 times more (faster) than global average.
- Summer Arctic sea ice extent has been declining at around 10% per decade.



Average Monthly Arctic Sea Ice Extent
August 1979 - 2013



“Slowing Down” of Atmospheric Circulation



- Slower jet stream leads to higher amplitude, slower moving waves.
- More “blocking” events, droughts, floods, heat waves, cold spells.

Francis And Vavrus (2012) – GRL
Hanna et al., (2013) - IJC
Barnes ((2013) - GRL



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