Forecast El Niño–Southern Oscillation Phases and Best Irrigation Strategies to Increase Cotton Yield

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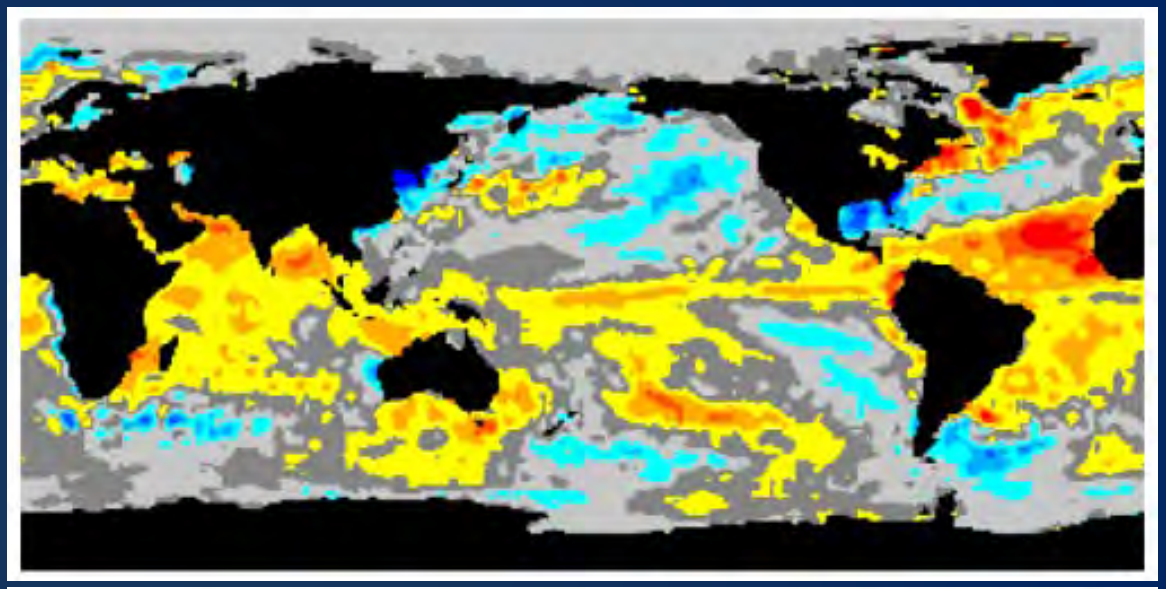
SOUTH DAKOTA
WY
NEBRASKA
COLORADO
KANSAS
OKLAHOMA
NM
TEXAS


Jan. 1938, 130 ft. lift, 1400 GPM

Relative Equatorial Pacific Sea Surface Temperatures

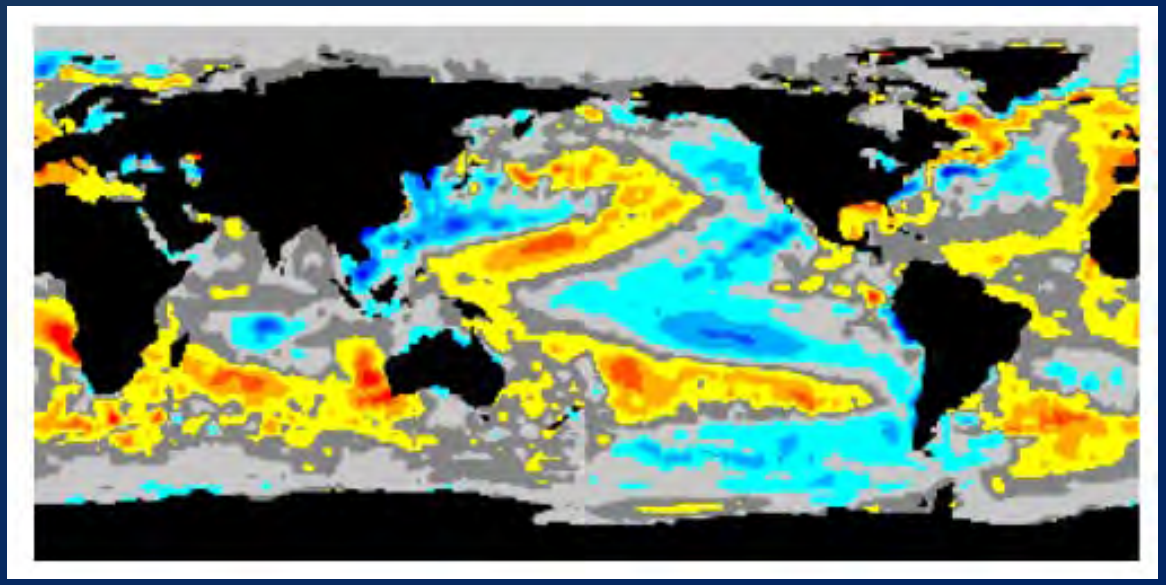
El Niño

Bushland rain in April 2010 was 4” or ~300% of monthly average,

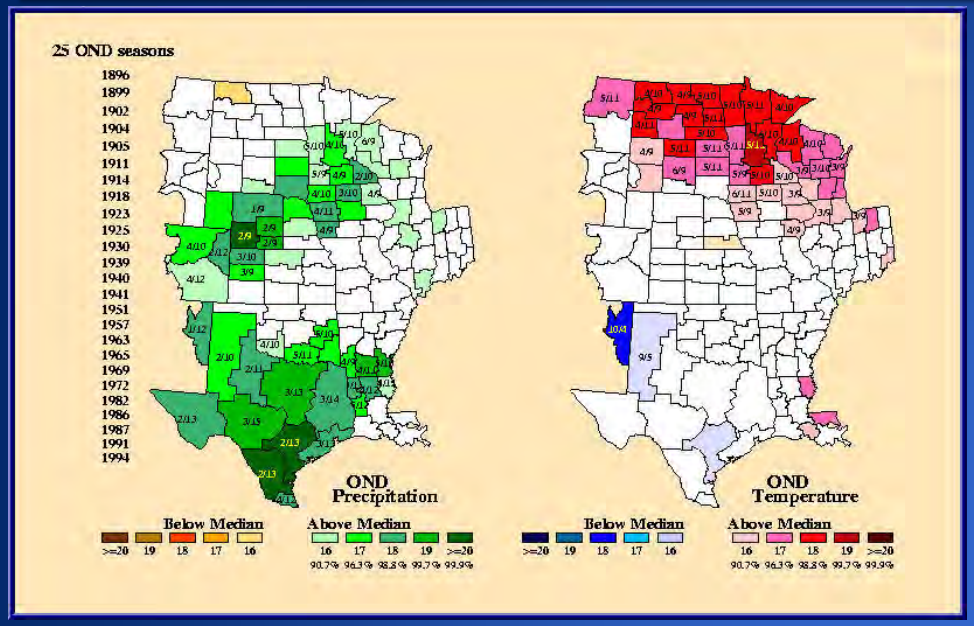


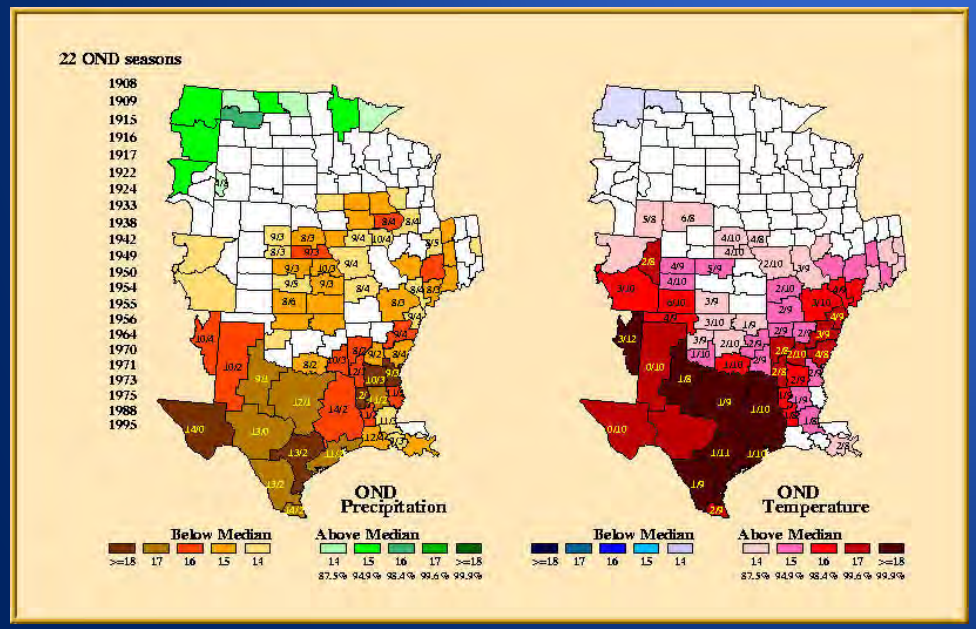
La Niña

in 2011 April rain was less than 0.1”.



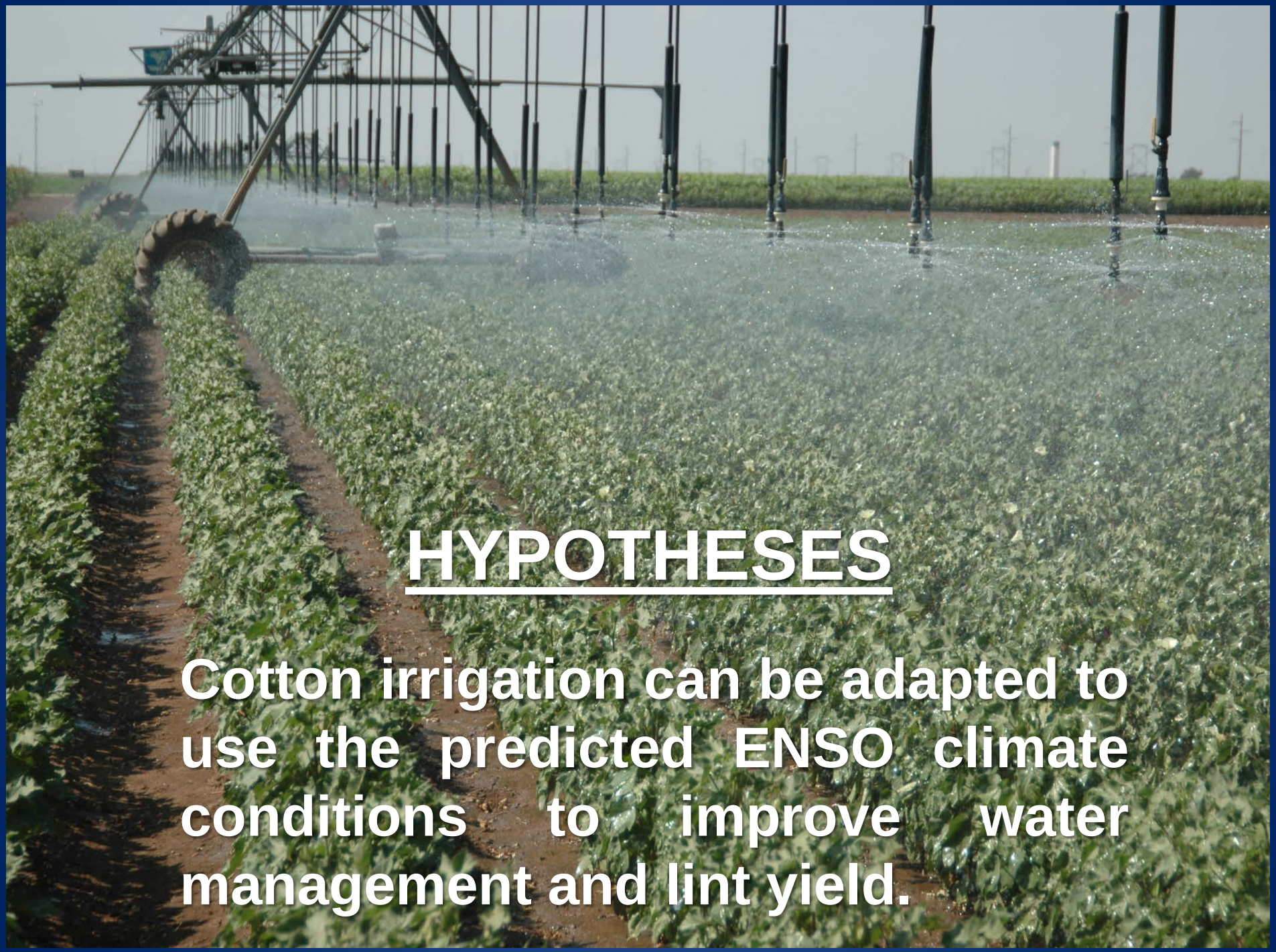
October-December El Niño Southern Oscillation (ENSO)





El Niño phase: Great Plains weather has more rain and lower temperatures

La Niña phase: Features reduced rain and warmer temperatures.



HYPOTHESES

Cotton irrigation can be adapted to use the predicted ENSO climate conditions to improve water management and lint yield.

OBJECTIVE

- Optimize cotton yield under variable rate irrigation applications as altered by ENSO phase.

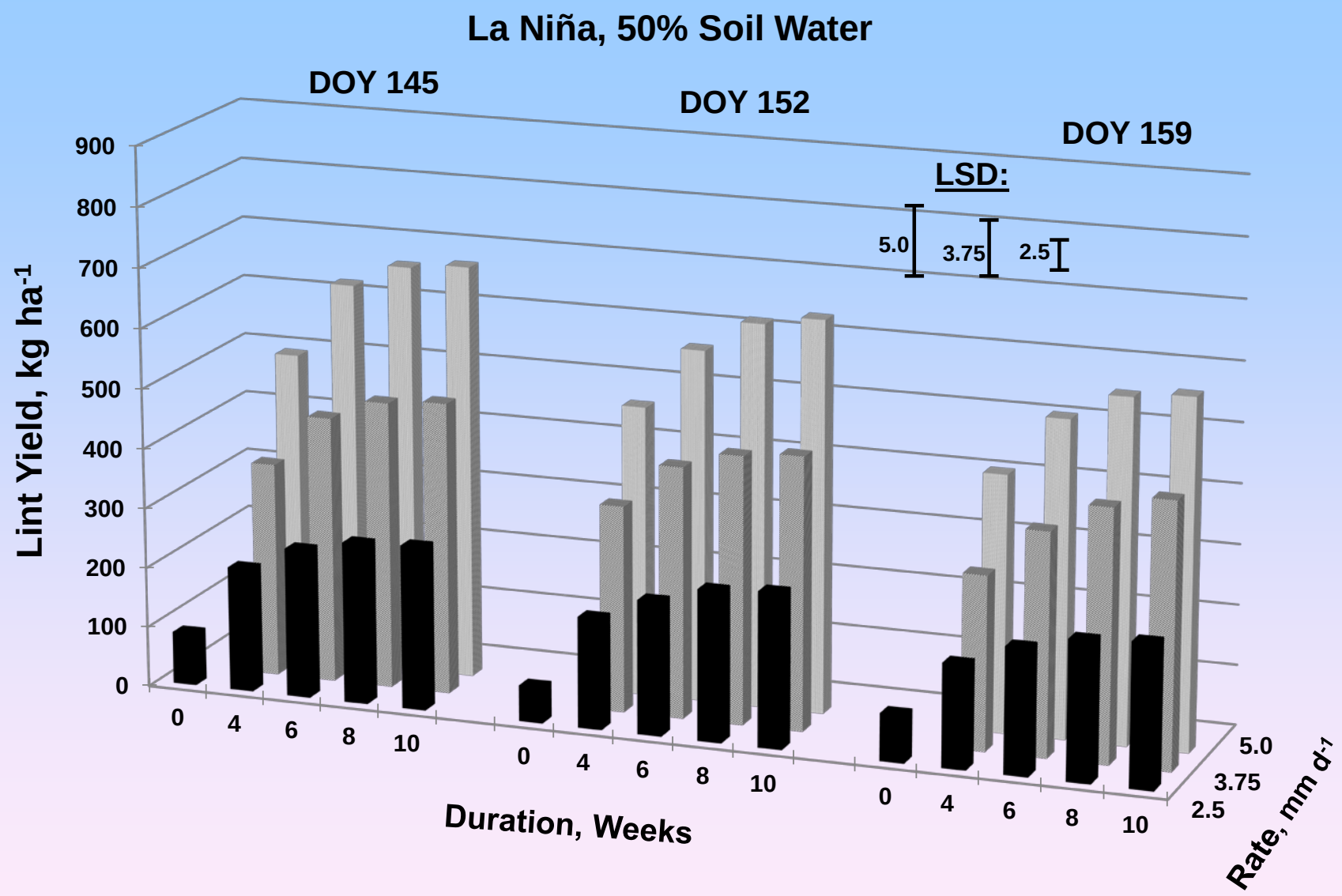
- This was achieved using GOSSYM simulated cotton response to initial soil water, emergence date, and irrigation rate and duration for years designated as La Niña, Neutral, and El Niño phase.

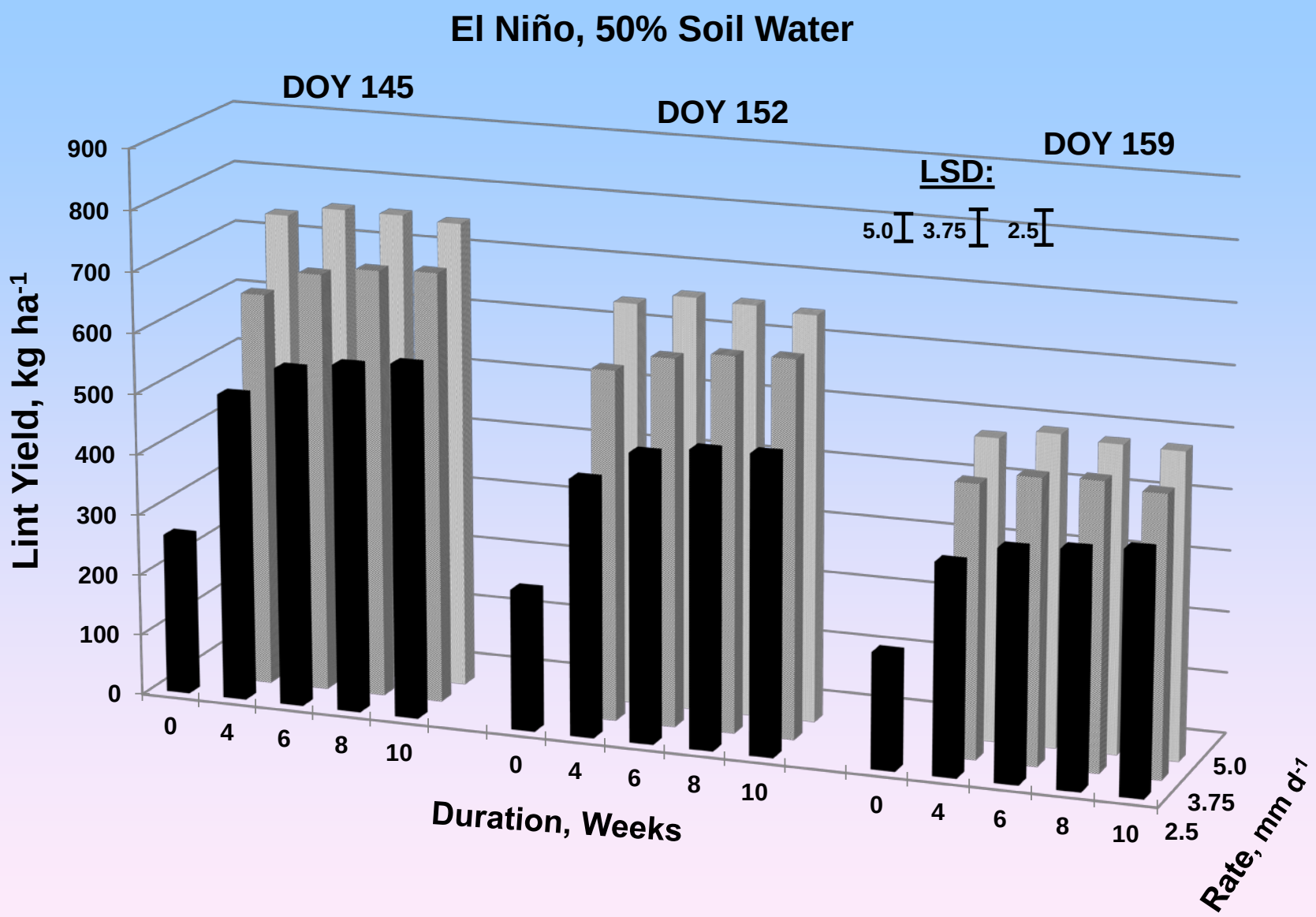
SIMULATIONS

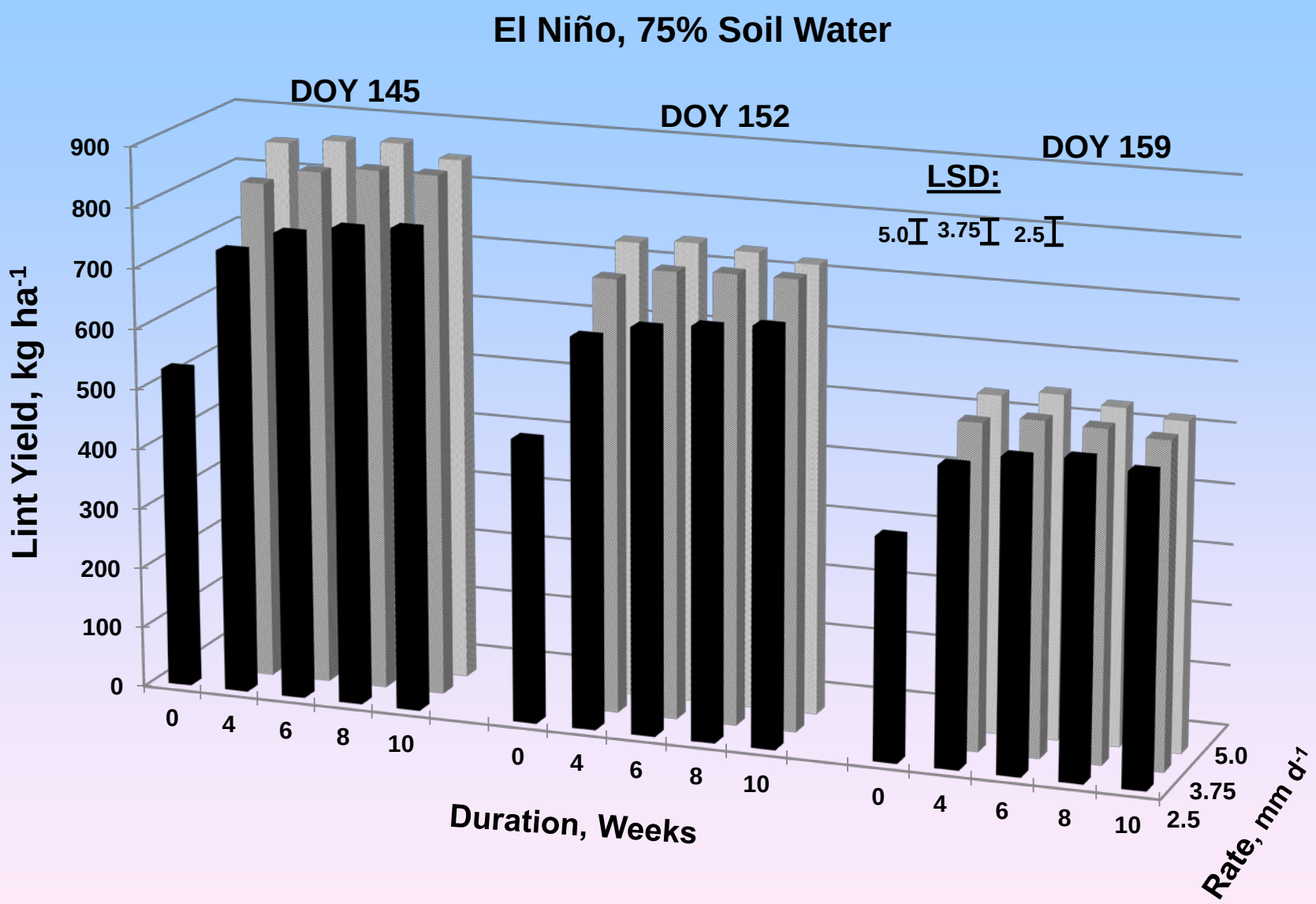
- We simulated yield of a stripper type cotton planted in 0.76 m (30”) rows at 13 plants m^{-2} (3/ft) and emerging on DOY 145, 152, and 159.
- Input weather from long-term (1959-2000) records at Bushland was daily: wind run, solar irradiance, maximum and minimum air temperature, and rain.
- ENSO phase determined from mean sea-surface temperature anomalies in the Niño 3.4 region (5° N–5° S, 120°–170° W) for:
  - i) 5-months centered on September and October,
  - ii) 3-months ending June (AMJ).

IRRIGATION PARAMETERS

- Irrigation – Rates (4):
  - Irrigation = 2.5 mm d^{-1} (2 gpm/ac)
  - Irrigation = 3.8 mm d^{-1} (3 gpm/ac)
  - Irrigation = 5.0 mm d^{-1} (4 gpm/ac)
  - No – Irrigation = Rain only
- Application Duration (4):
  - 4, 6, 8, and 10 weeks beginning 30 June after AMJ designation of ENSO phase


La Niña, 50% Soil Water
DOY 145
DOY 152
DOY 159
LSD:
5.0
3.75
2.5
Lint Yield, kg ha-1
900
800
700
600
500
400
300
200
100
0
0
4
6
8
10
Duration, Weeks
5.0
3.75
2.5
Rate, mm d-1


El Niño, 50% Soil Water
DOY 145
DOY 152
DOY 159
LSD:
5.0
3.75
2.5
Lint Yield, kg ha-1
900
800
700
600
500
400
300
200
100
0
0
4
6
8
10
Duration, Weeks
5.0
3.75
2.5
Rate, mm d-1

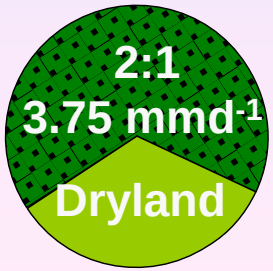

El Niño, 75% Soil Water
DOY 145
DOY 152
DOY 159
LSD:
5.0
3.75
2.5
Lint Yield, kg ha-1
900
800
700
600
500
400
300
200
100
0
0
4
6
8
10
Duration, Weeks
5.0
3.75
2.5
Rate, mm d-1

DESIGNATED LA NIÑA AND EL NIÑO YEARS: APRIL-JUNE (AMJ), SEPTEMBER-OCTOBER (S-O).

Years - La Niña Cold (< -0.5 ºC) Phase			Years - El Niño Warm (> 0.5 ºC) Phase		
S-O 5-mo. avg.		AMJ 3 mo. avg.	S-O 5-mo. avg.		AMJ 3 mo. avg.
1964	->	1964	1963	x	~~1963~~
1970	x	~~1970~~	1965	->	1965
1971	->	1971	1968	x	~~1968~~
1973	->	1973	1969	->	1969
1974	->	1974	1972	->	1972
1975	->	1975	1976	x	~~1976~~
1988	->	1988	1977	x	~~1977~~
1998	x	~~1998~~	1982	->	1982
1999	->	1999	1986	x	~~1986~~
2000	->	2000	1987	->	1987
			1991	->	1991
	+	1985	1993	->	1993
	+	1989	1994	->	1994
			1997	->	1997
				+	1961
				+	1966
				+	1983
				+	1992
				+	1998

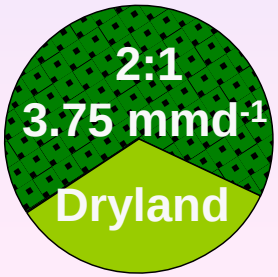
Simulated average net lint yield for La Niña phase years (AMJ) with 50% initial soil water content and irrigated with 70 or 140 –mm at 2.5, 3.75, or 5.0 mm d^{-1} application rates for 4 and 8 -weeks using uniform, 2:1, and 1:1 irrigation strategies.

		50% Initial Soil Water					
		4-Week Duration			8-Week Duration		
Application Strategy	Irrigation Rate	Lint Yield	70 mm Net-Mean Yield	Fraction of Base Yield	Lint Yield	140 mm Net-Mean Yield	Fraction of Base Yield
	mm d^{-1}	kg ha^{-1}		%	kg ha^{-1}		%
Dryland	0.0	130			130		
Uniform	2.5	260	260	**100**	320	320	123
2:1	3.75	420	320	123	530	400	154
	0.0	130			130		
1:1	5.0	570	350	135	680	400	154
	0.0	130			130		



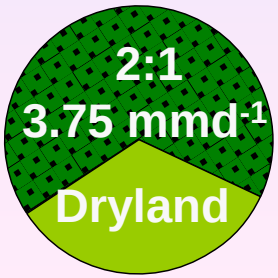
Effects of initial soil water and emergence day of year (DOY) on simulated lint yields of cotton irrigated 4 or 8 weeks with uniform, 2:1, or 1:1 irrigation strategies delivering 70 and 140 mm during AMJ classified La Niña phase years.

		50% Initial Soil Water						75% Initial Soil Water				
DOY La Niña	Irrigation Rate mm d^{-1}	4-week	70 mm		8-week	140 mm		4-week	70 mm		8-week	140 mm
		Lint Yield, kg ha^{-1}										
145	0.0	130			130			310			310	
Uniform	2.5	260	260		320	320		480	480		570	570
	3.75	420	320	2:1	530	400	2:1	620	520	2:1	740	600
	5.0	570	350	1:1	680	400	1:1	730	520	1:1	830	570
152	0.0	90			90			270			270	
Uniform	2.5	220	220		280	280		410	410		500	500
	3.75	380	280	2:1	480	350	2:1	530	440	2:1	620	500
	5.0	490	290	1:1	590	340	1:1	620	440	1:1	680	470
159	0.0	90			90			240			240	
Uniform	2.5	180	180		220	220		350	350		430	430
	3.75	310	240	2:1	400	300	2:1	450	380	2:1	530	430
	5.0	420	250	1:1	500	300	1:1	510	370	1:1	560	400

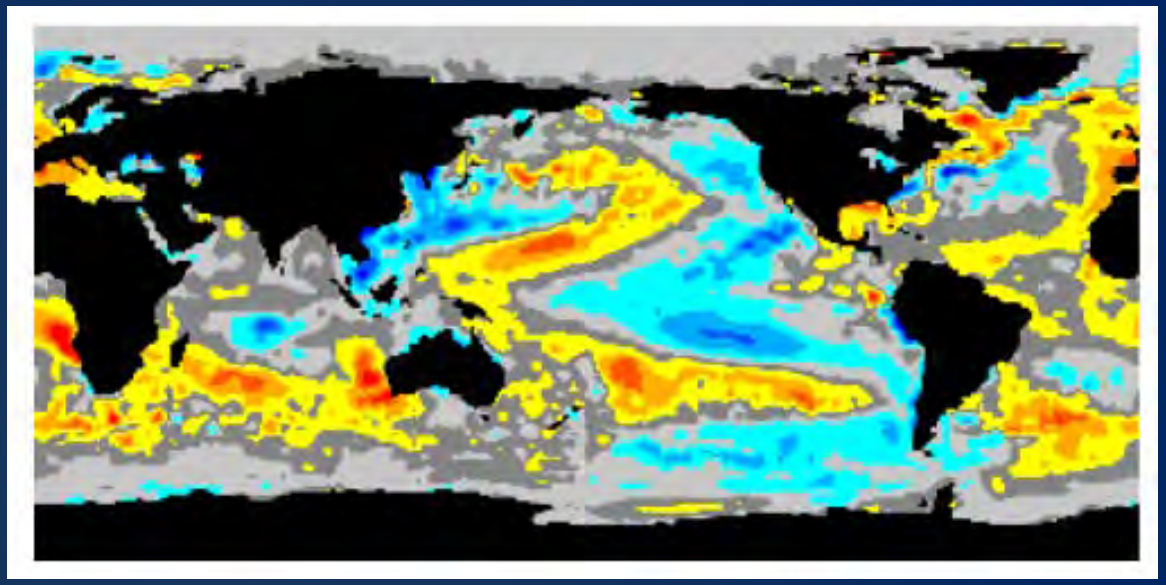


Effects of initial soil water and AMJ classified ENSO phase on simulated lint yields of DOY 145 cotton irrigated 4 or 8 weeks with uniform, 2:1, or 1:1 irrigation strategies delivering 70 and 140 mm.

		50% Initial Soil Water						75% Initial Soil Water					
Phase	Irrigation Rate mm d^{-1}	4-week	70 mm		8-week	140 mm		4-week	70 mm		8-week	140 mm	
		Lint Yield, kg ha^{-1}											
La Niña	0.0	130			130			310			310		
Uniform	2.5	260	260		320	320		480	480		570	570	
	3.75	420	320	2:1	530	400	2:1	620	520	2:1	740	600	
	5.0	570	350	1:1	680	400	1:1	730	520	1:1	830	570	
Neutral	0.0	280			280			490			490		
Uniform	2.5	450	450		520	520		650	650		720	720	
	3.75	600	500	2:1	700	560	2:1	760	670	2:1	810	710	
	5.0	730	510	1:1	790	540	1:1	820	660	1:1	850	670	
El Niño	0.0	210			210			430			430		
Uniform	2.5	410	410		480	480		610	610		680	680	
	3.75	540	430	2:1	600	470	2:1	740	640	2:1	820	690	
	5.0	640	430	1:1	710	460	1:1	800	620	1:1	870	650	



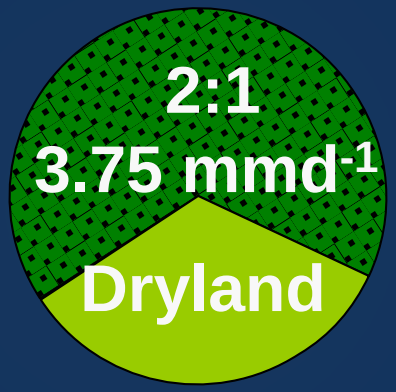
Summary



Because the relatively cooler equatorial pacific sea surface temperatures are a result of deeper ocean currents and are more independent of “seasonal locking”, the La Niña phase may be more accurately classified early enough to direct irrigation management strategies.

Summary

- Focused-application irrigation strategies increased net lint yield during the drier La Niña phase years.



- In contrast, "Water Spreading" or uniform irrigation strategies optimized net lint yield during the El Niño phase.

Conclusions

For the efficient use of precipitation to extend water resources and for optimizing net cotton lint yields, we conclude that focused partial pivot irrigation strategies are better suited for use during a forecasted drier

La Niña phase.