Chesapeake Bay climate extremes and variability: a recent past, present, and near future analysis

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Who: The faces of our team

NOAA*

UMCES

CEC

CBNERR-MD

Jenn Raulin
Sasha Land
Jenny Allen

NATIONAL ESTUARINE RESEARCH RESERVE SYSTEM

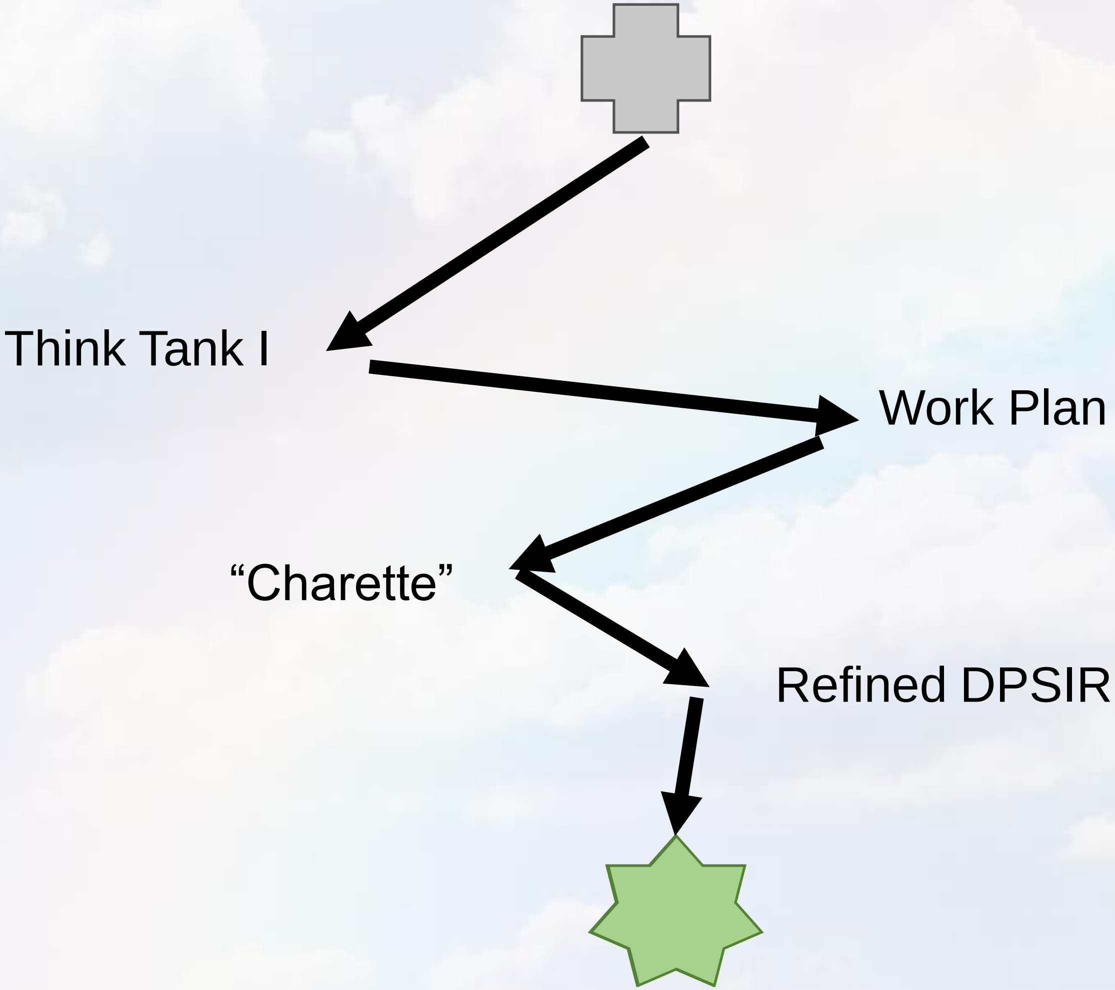
CBNERR-VA

Willy Reay
Sandra Erdle
Sarah Nuss
Ken Moore

***now at Campbell Foundation**

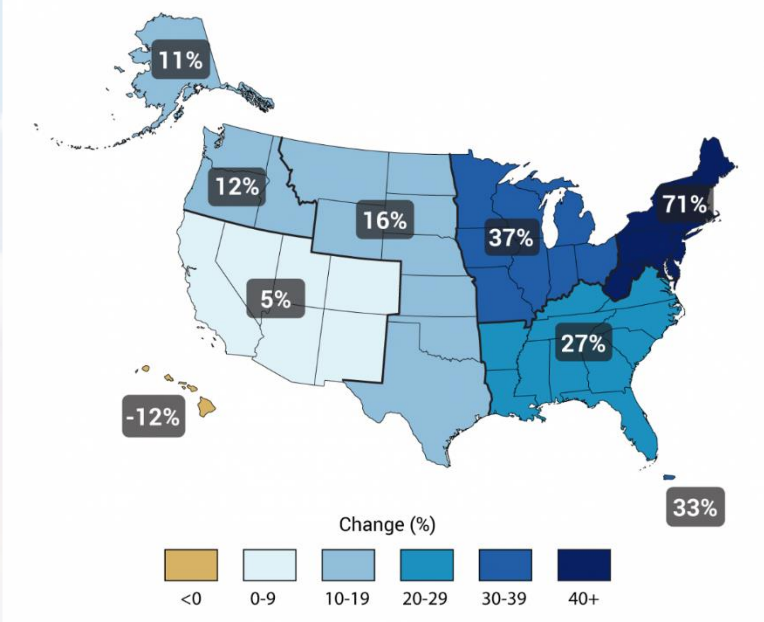
“Traditional Research Project”

“Our Approach”

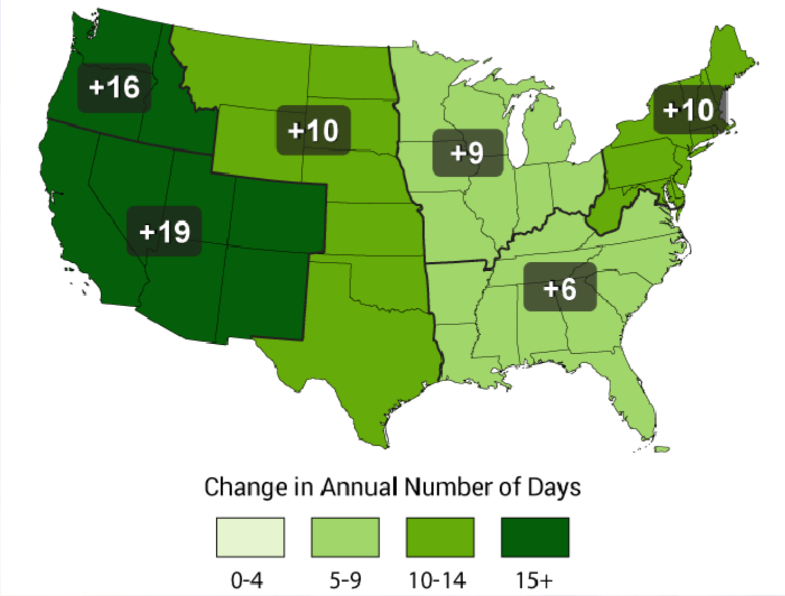


Chesapeake Bay is Divided!

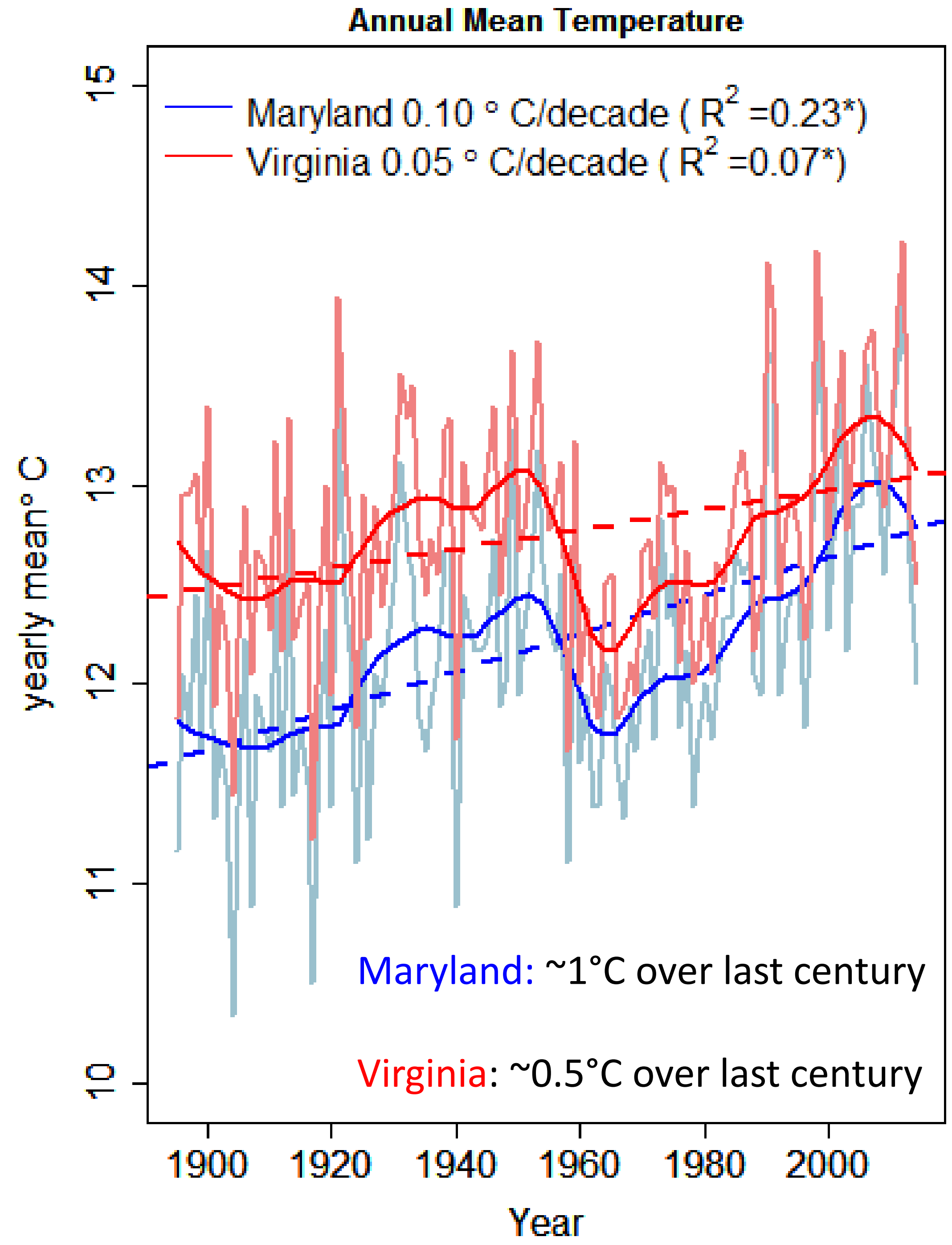
Observed Change in Very Heavy precipitation



Observed Increase in Frost Free Season Length



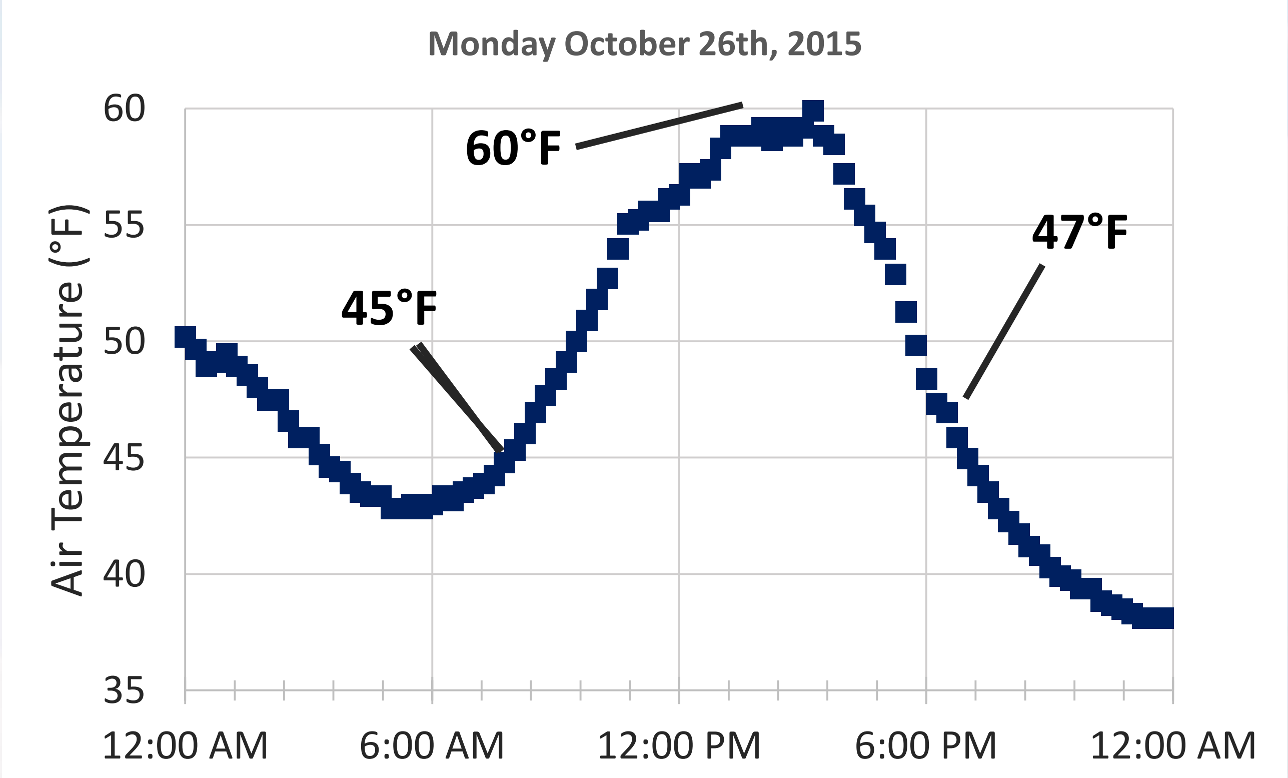
National Climate Assessment



Means vs Extremes

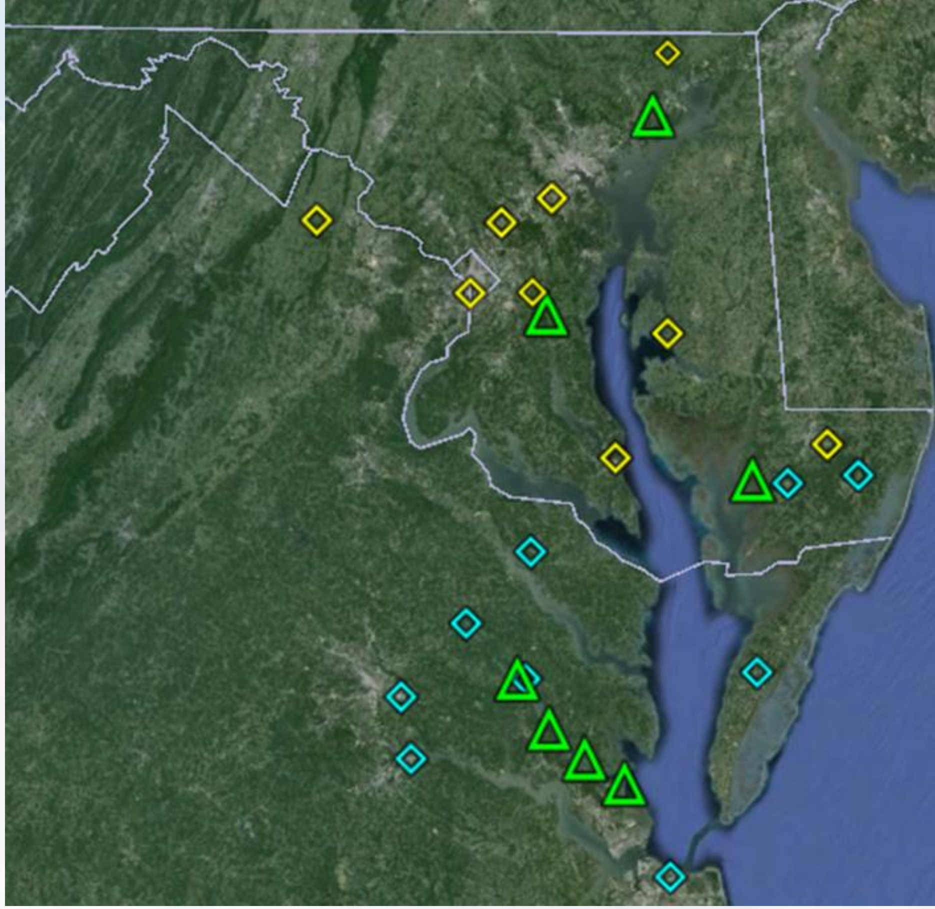
Organisms don't feel annual means

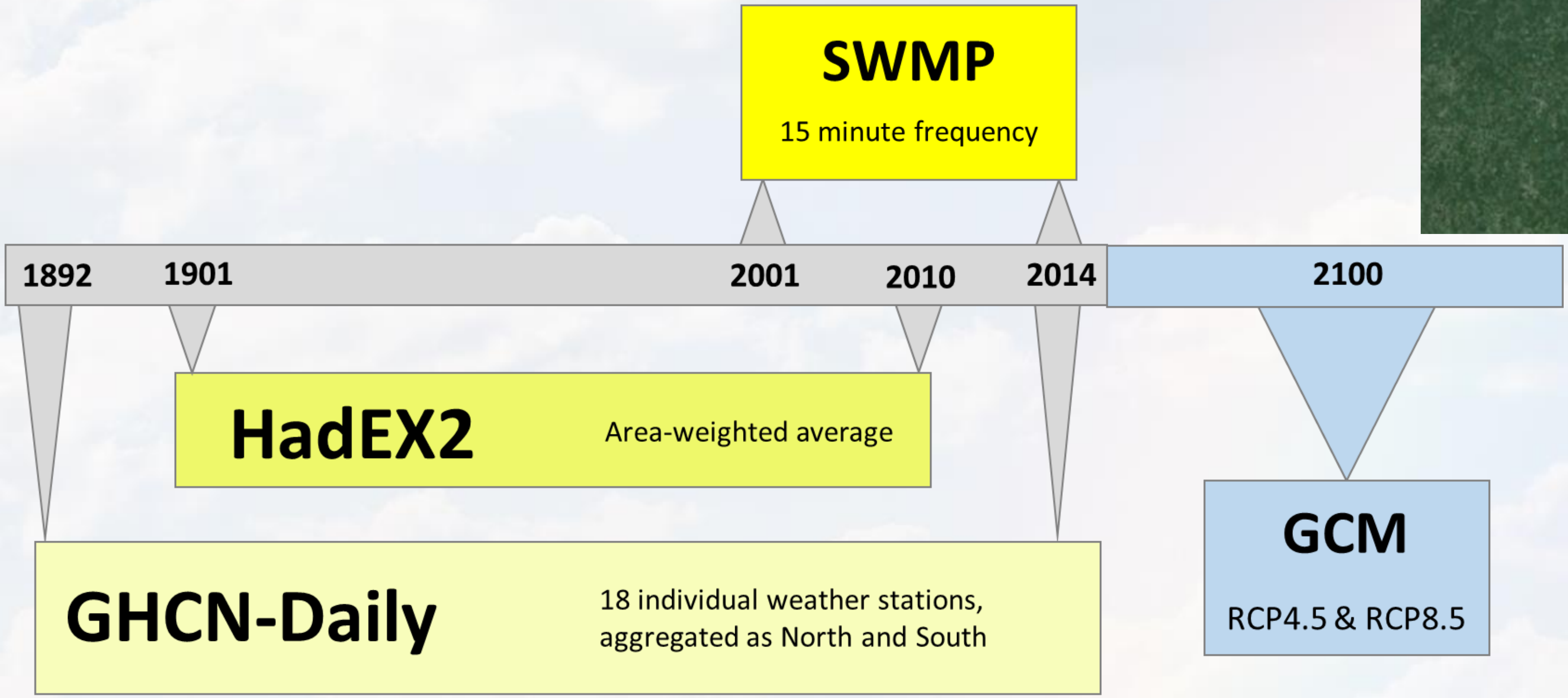
They feel **extremes** and **variability**



Climate Extremes Indices

- **Intensity:** what is the hottest temperature?
- **Frequency:** how many days were below freezing?
- **Duration:** How long is the growing season?

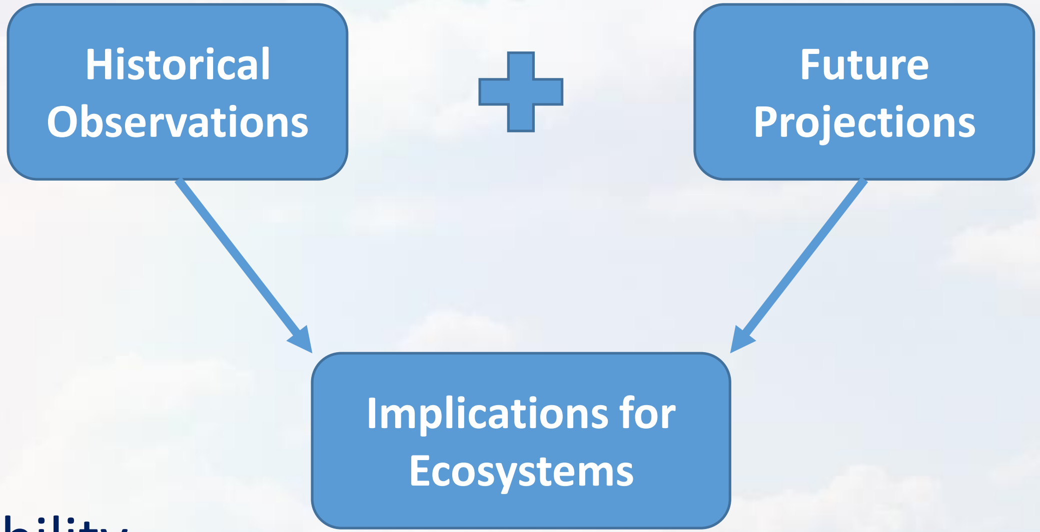




Ecological Applications of Climate Indices

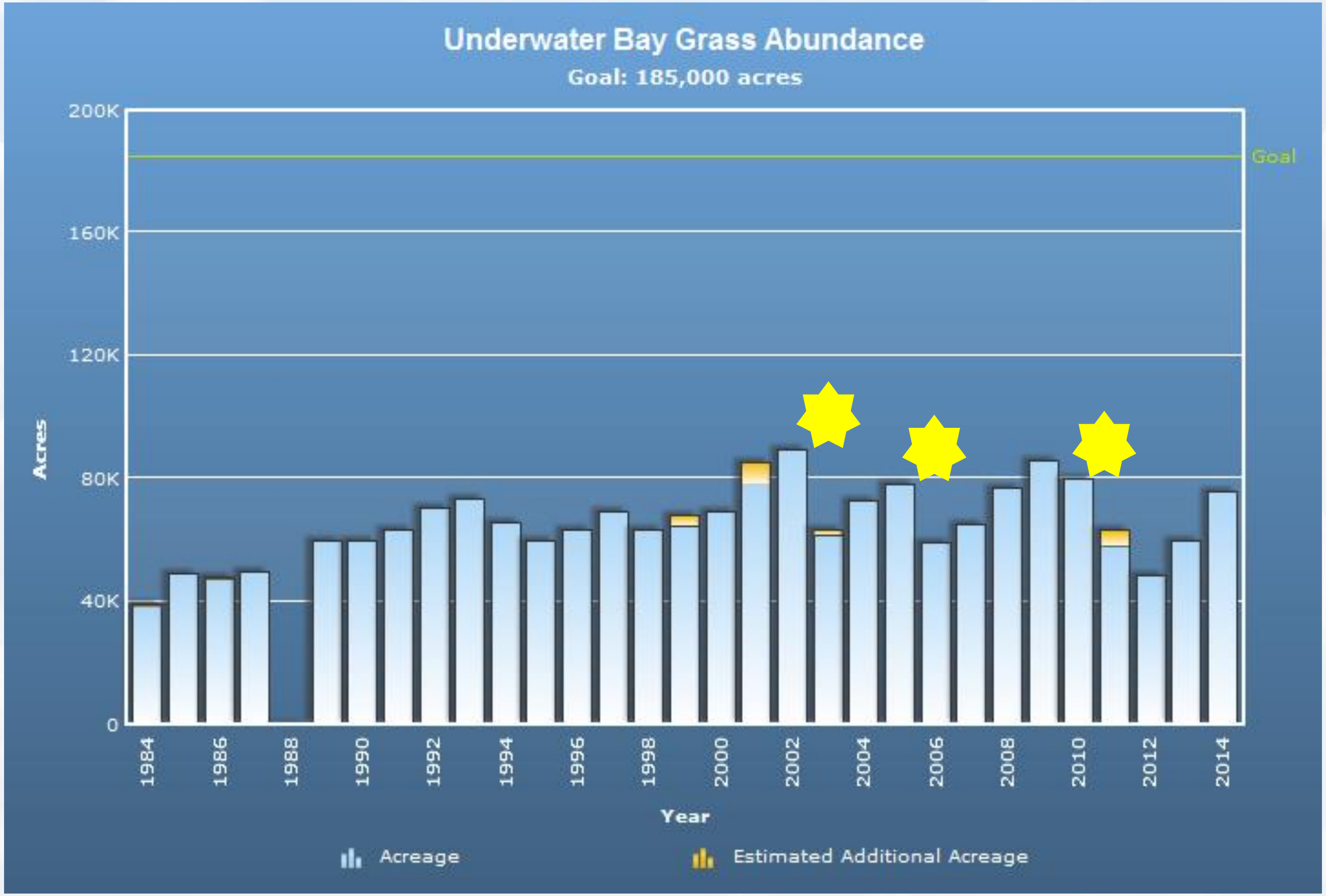
- 1) Percentage of warm days & SAV diebacks
- 2) Wet day frequency & annual nitrogen loading
- 3) Warm autumns + cold snaps & brown pelican deaths

NATIONAL ESTUARINE RESEARCH RESERVE SYSTEM



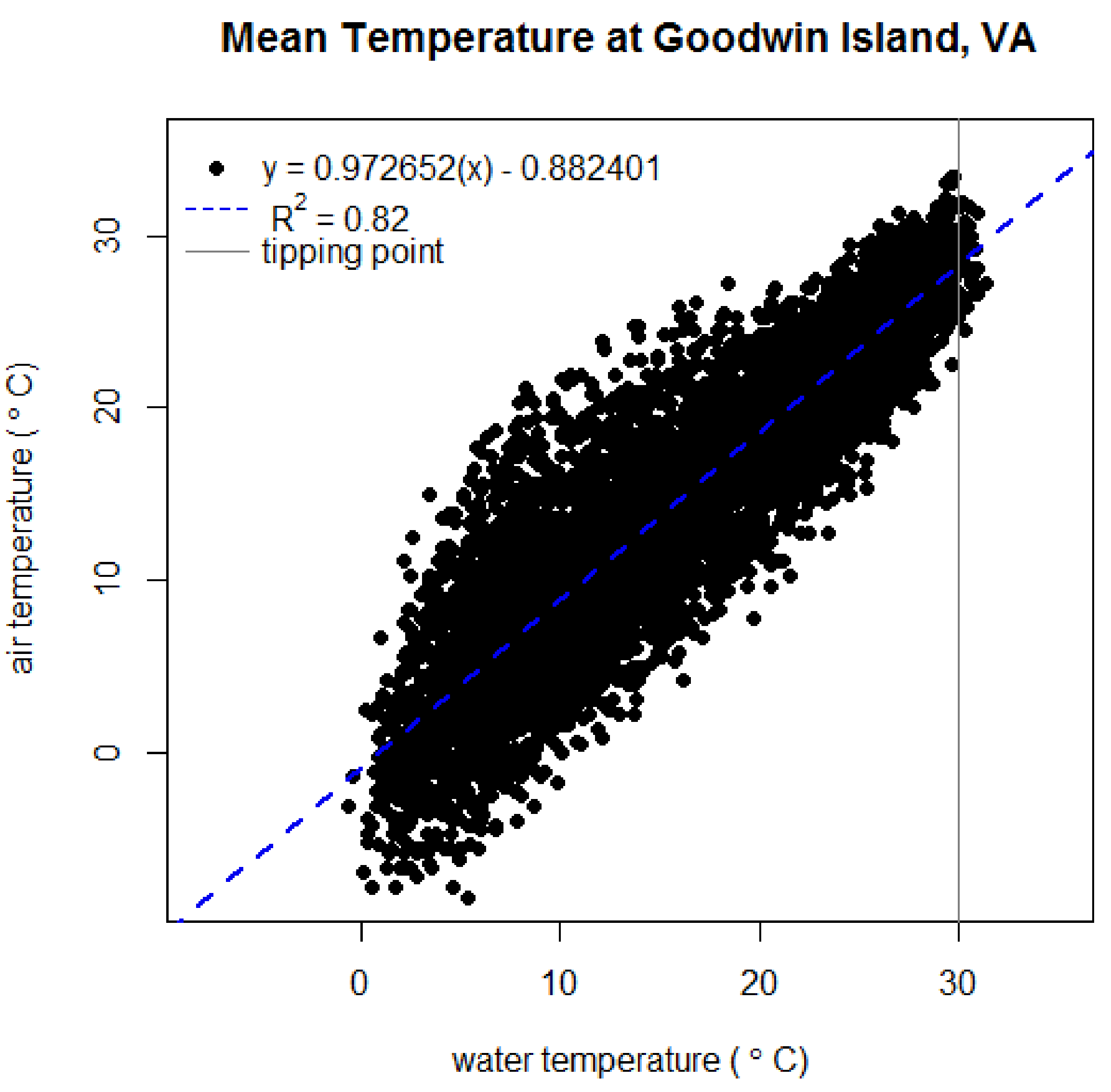
4) Coming soon: extension of GSL with Vibrio probability

Submerged Aquatic Vegetation: The Highs and Lows

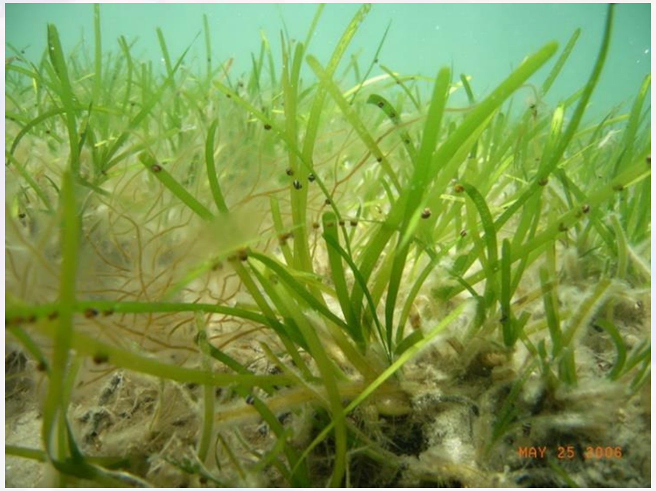


Virginia Institute of Marine Science; Chesapeake Bay Program, U.S. Fish and Wildlife Service

What happens in the air…happens in the Bay



Eelgrass gets stressed at temperature >30°C (86°F)



What ATemps are needed to get WTemp to 30°C?

Mean Air Temp

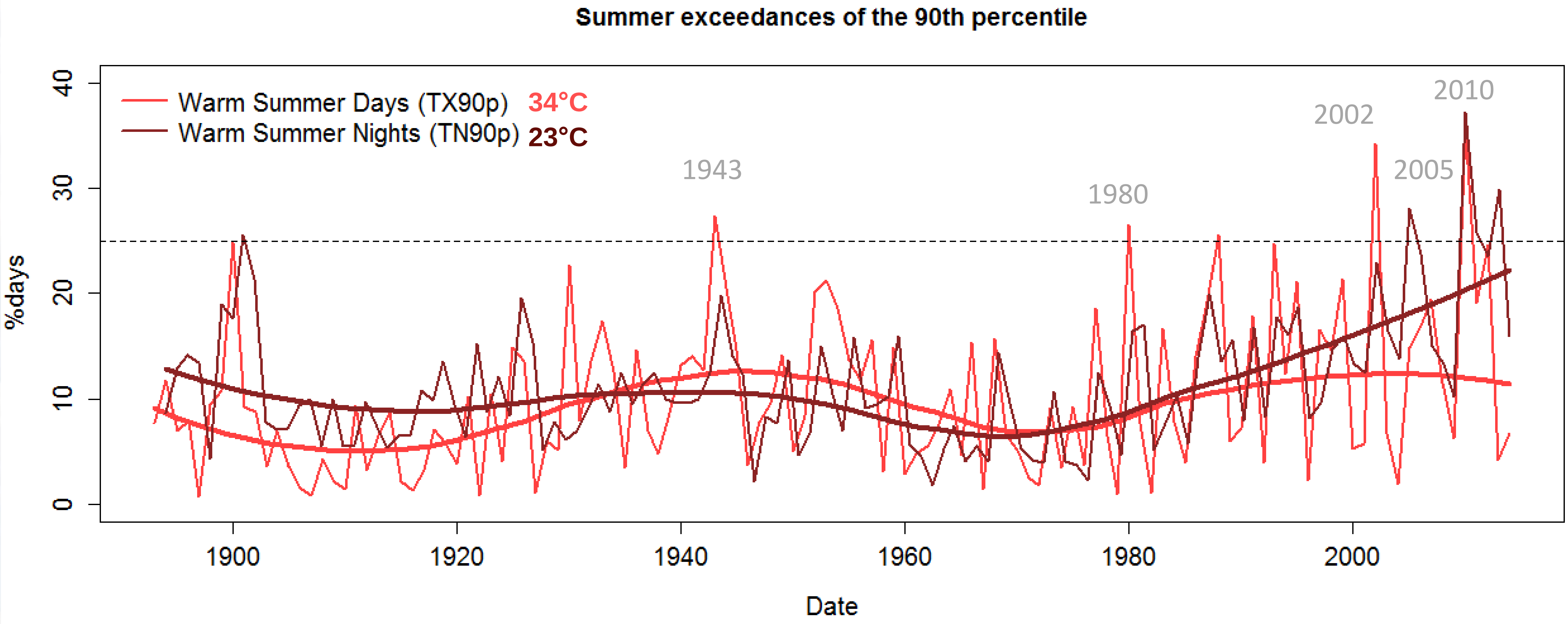
28°C

Range

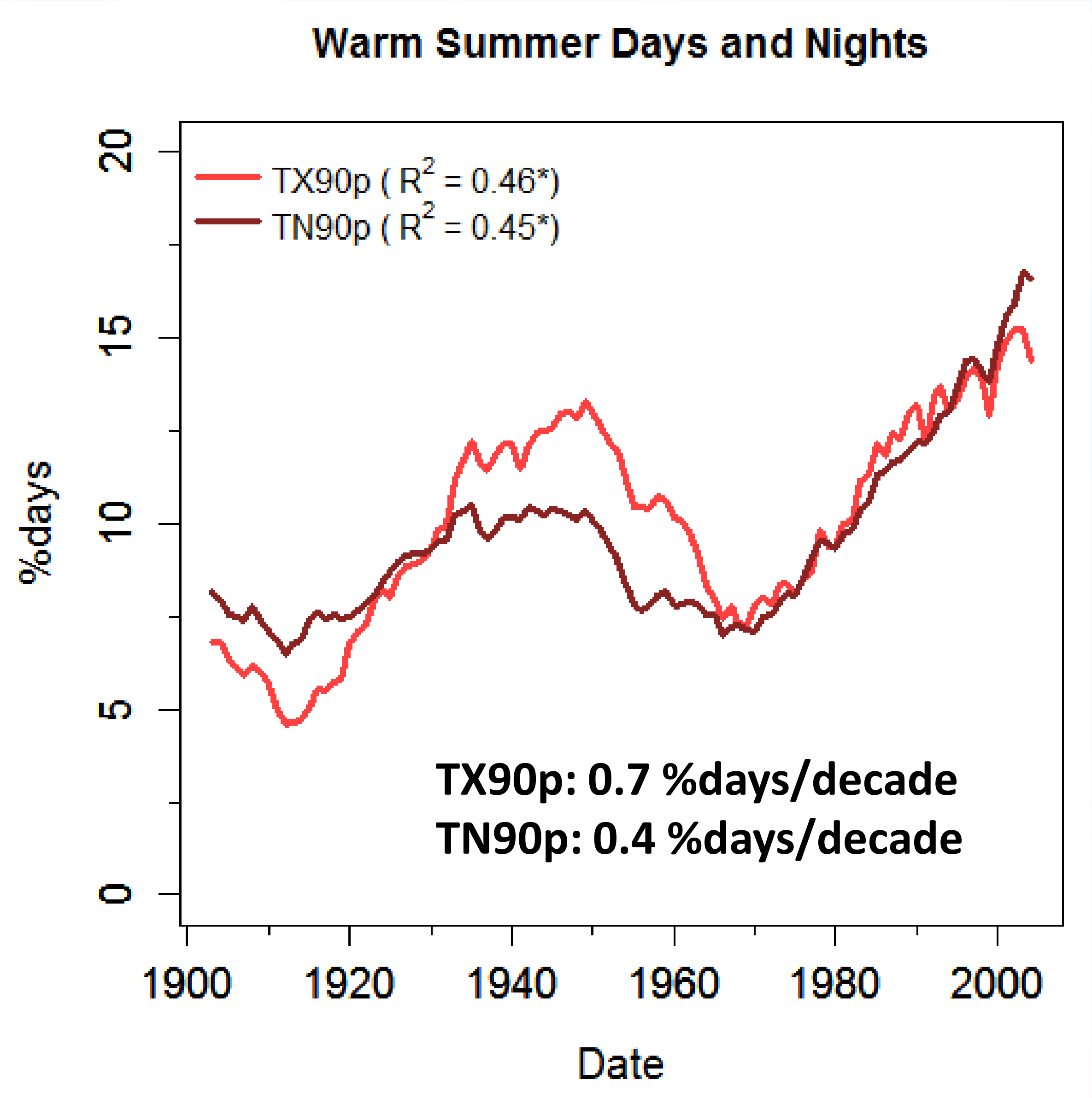
24 to 33°C

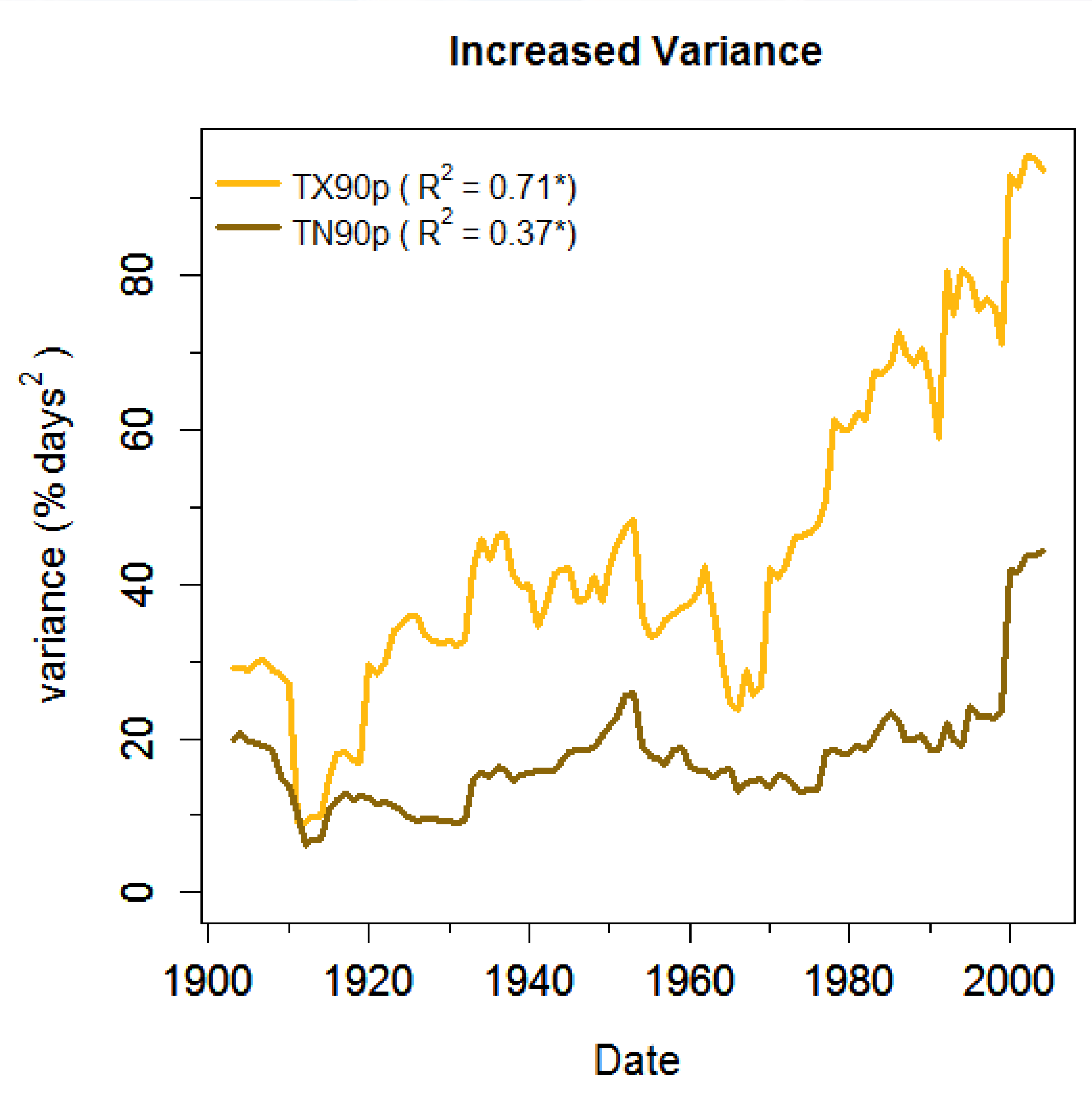
Frequency of warm summer days and nights

When >25% of summer is "extra" warm, we observed declines in SAV populations

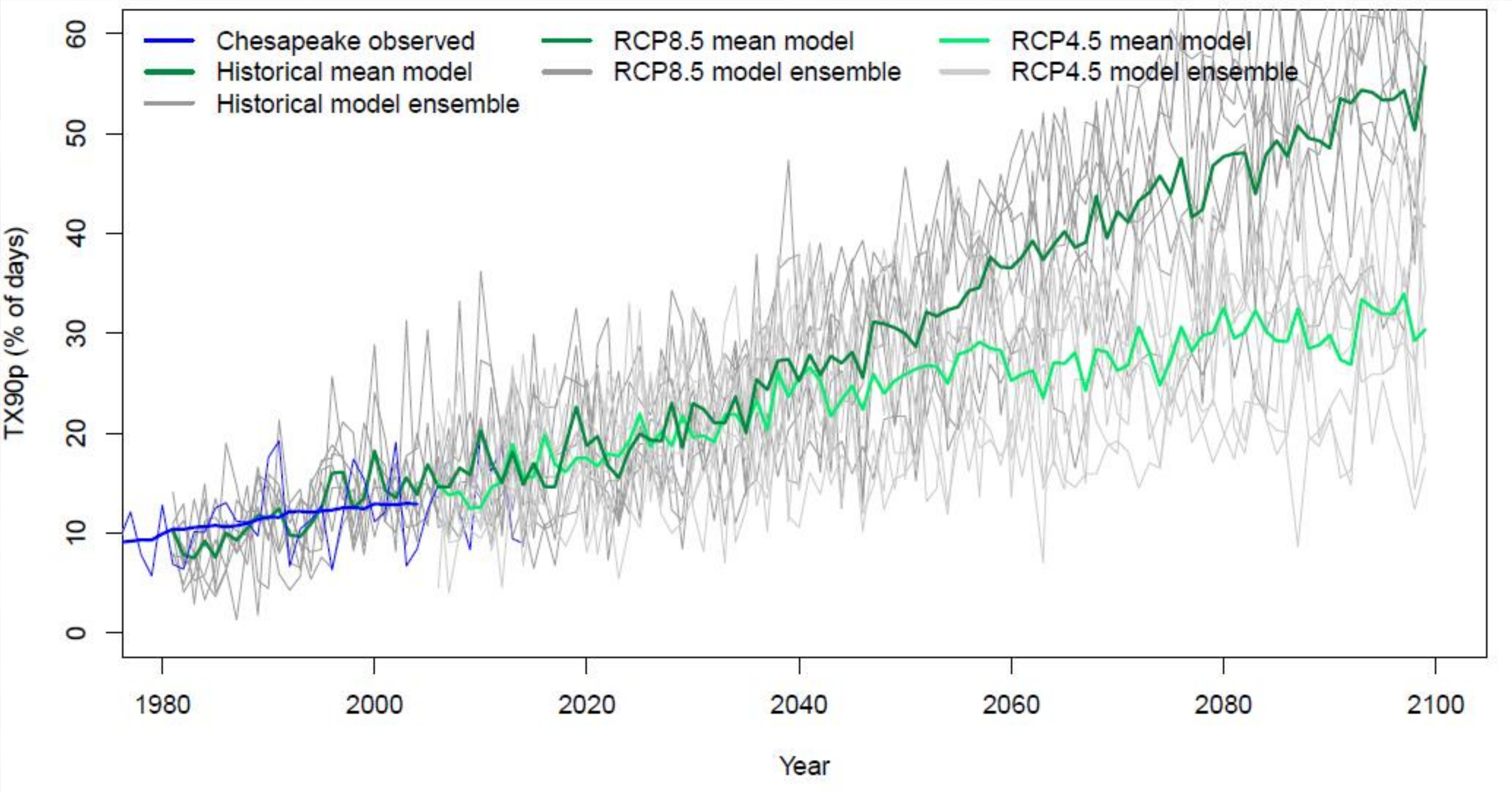


Frequency of warm summer days & SAV diebacks

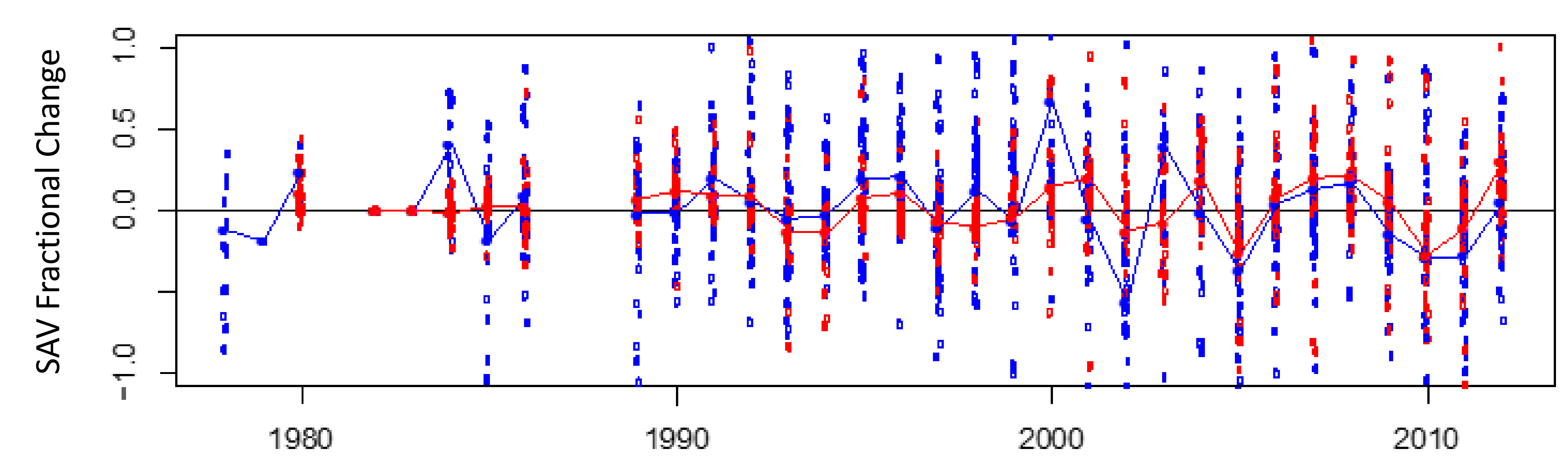


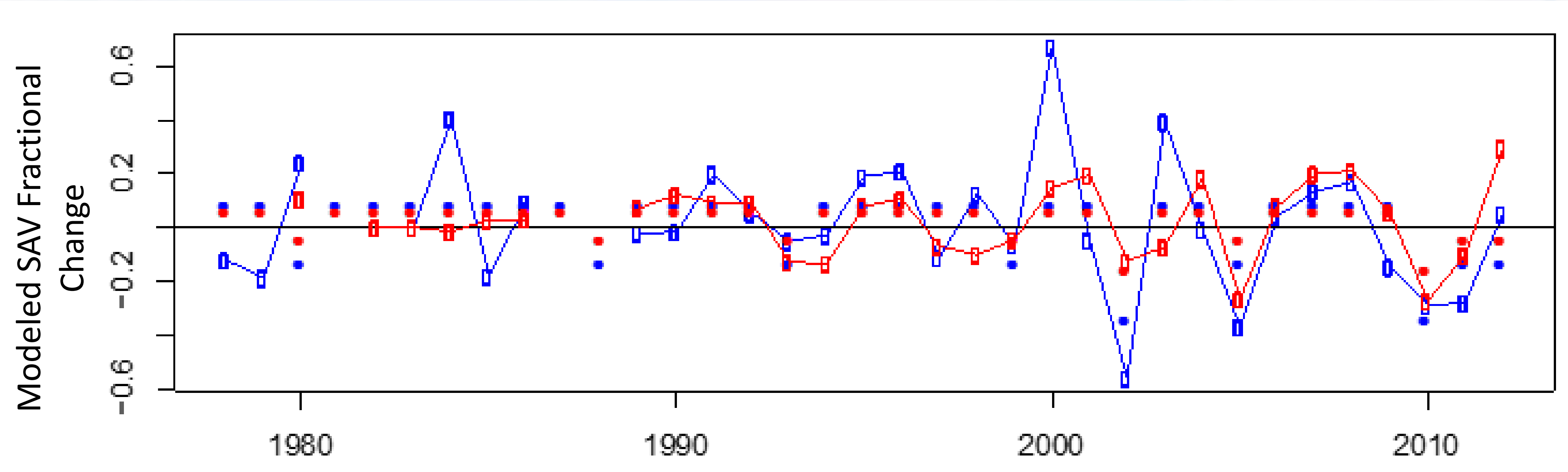


Future Projections: Continued Increases Expected

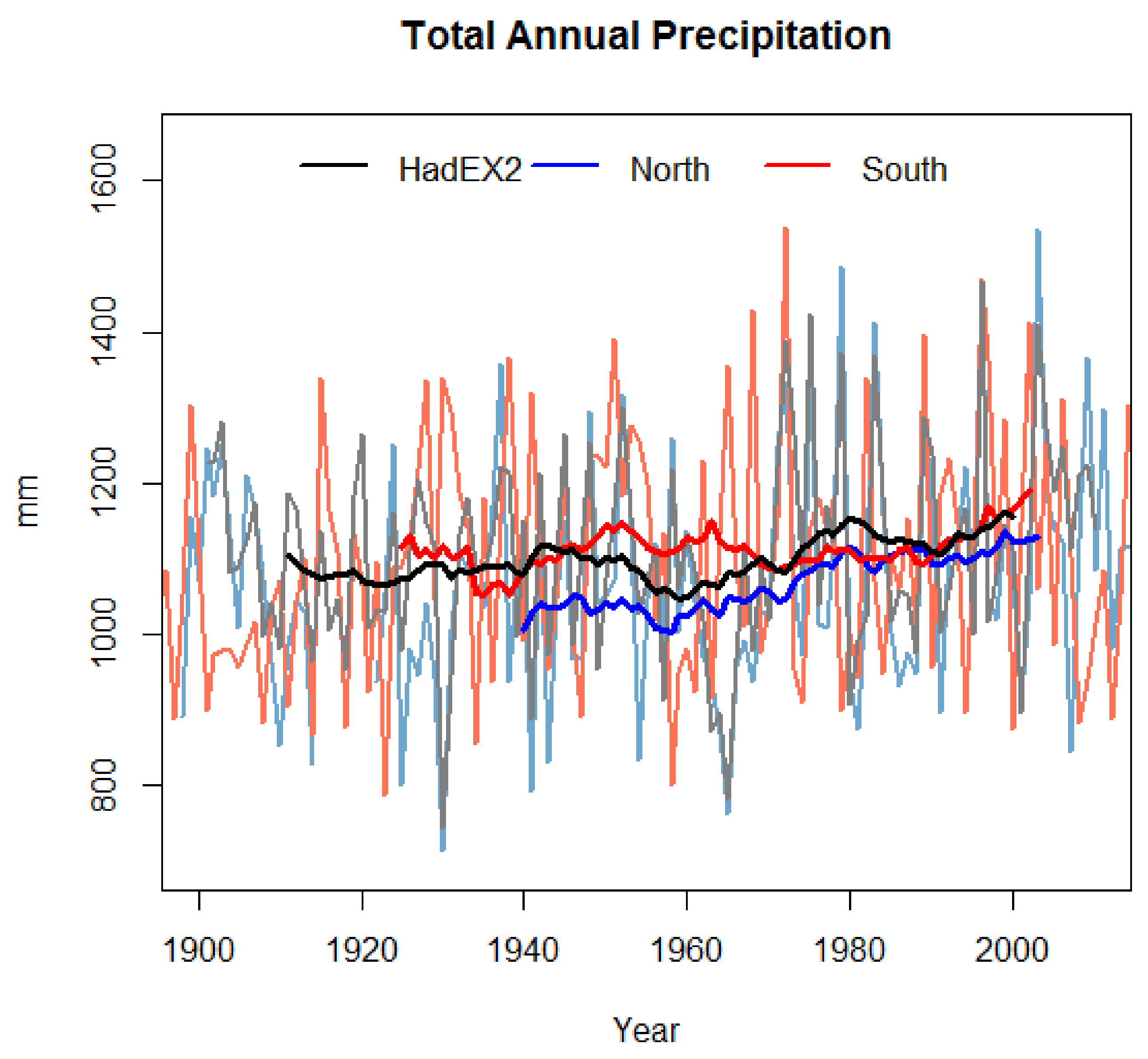


From Observations to Predictions





Historical Precipitation Observations



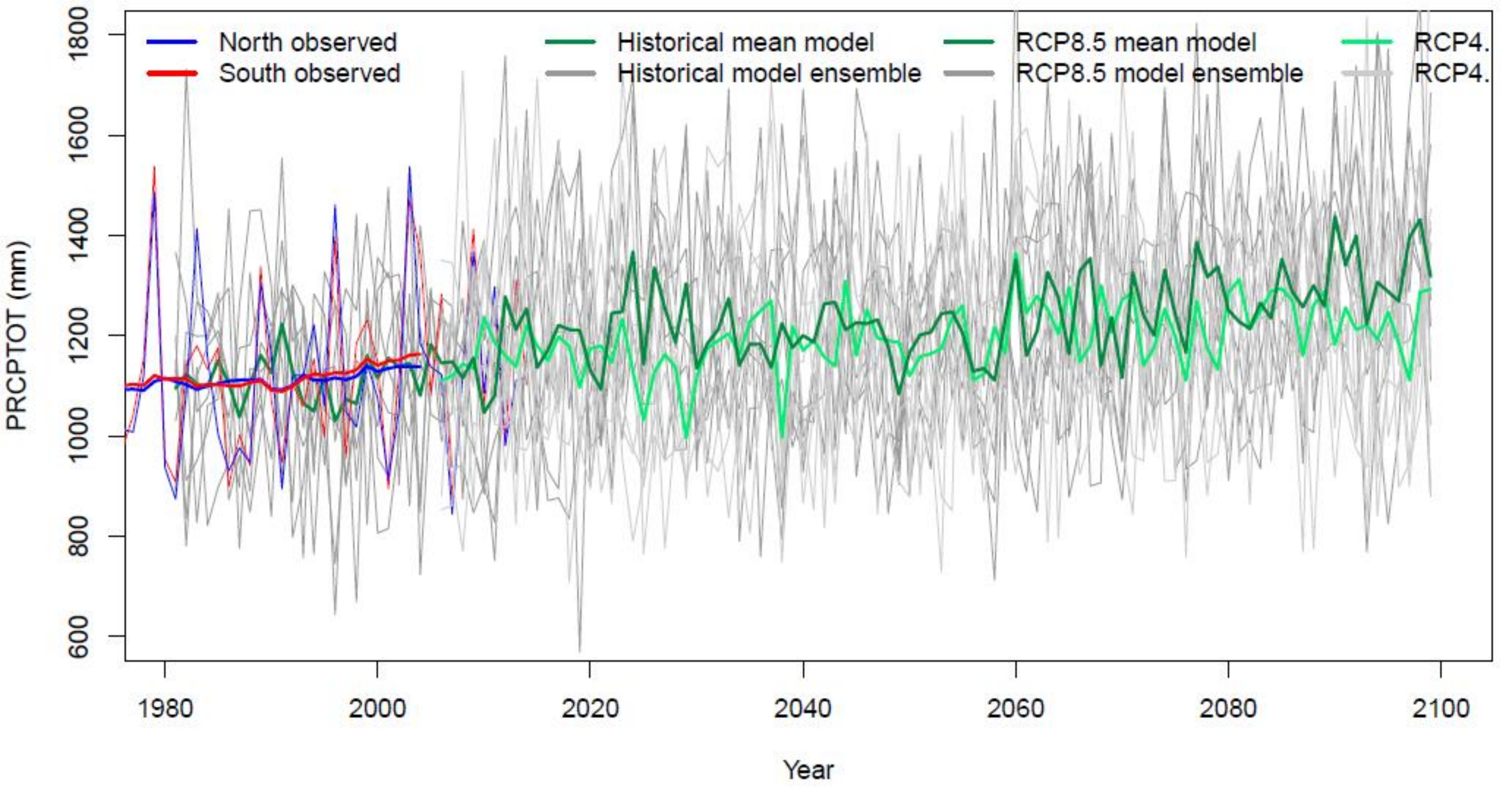
North: +16.8 mm/decade

South: +5.2 mm/decade

HadEX2: +6.8 mm/decade

Coefficient of variation significantly increased

Future Projections: Continued Increases Expected



Consistent with STAC report by Pyke and Najjar, 2008

Wet Day Frequency

Chesapeake Bay Program

MDDNR

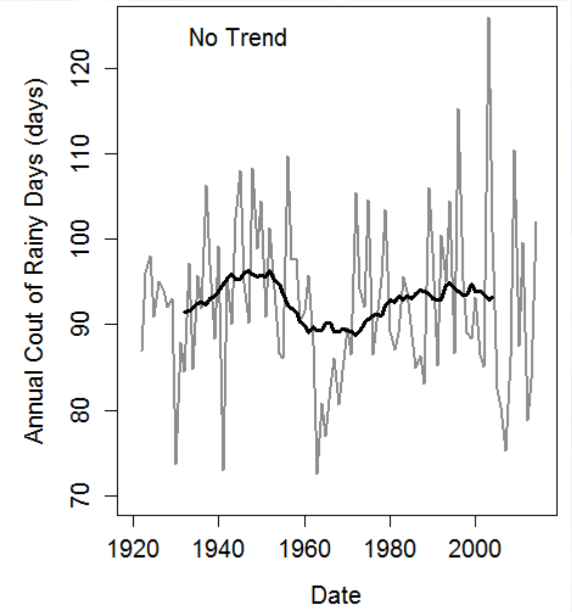
Rainy Days = Very Wet Days + Moderately Wet Days + Mildly Wet Days

$$\frac{PRCPTOT}{SDII}$$

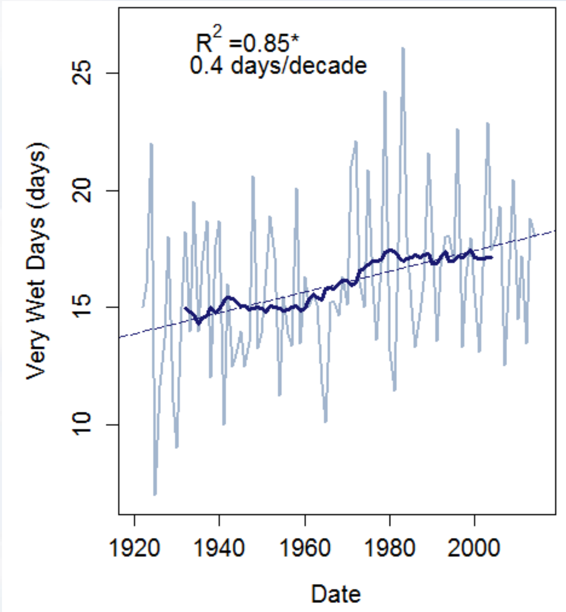
R20mm

R10mm -R20mm

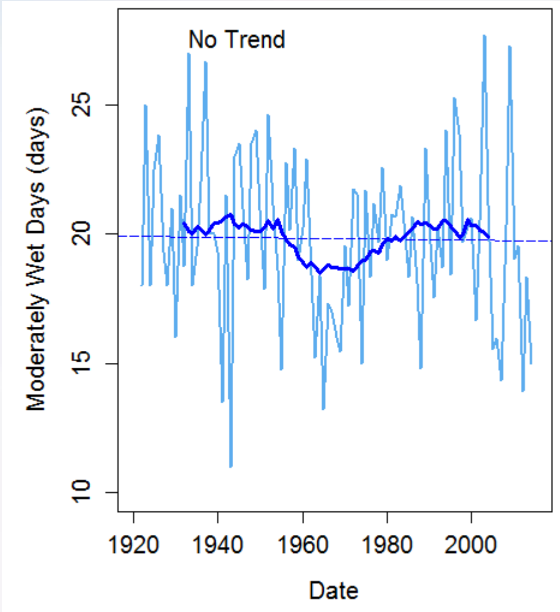
$$\left(\frac{PRCPTOT}{SDII}\right) - \text{R20mm} - (\text{R10mm-R20mm})$$



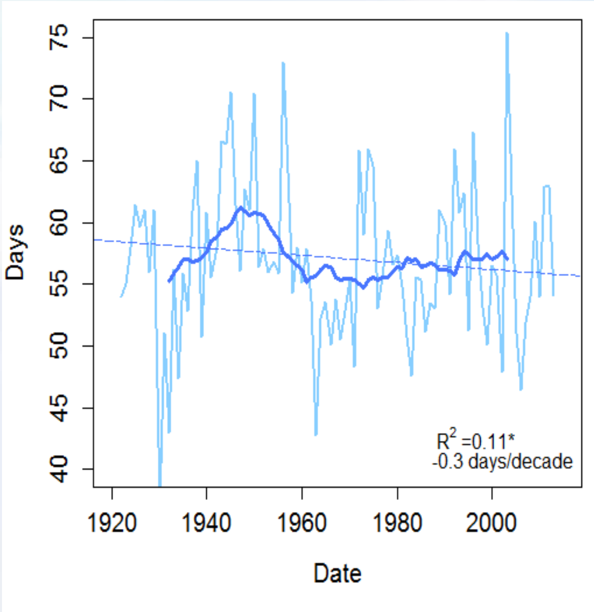
No Change



More

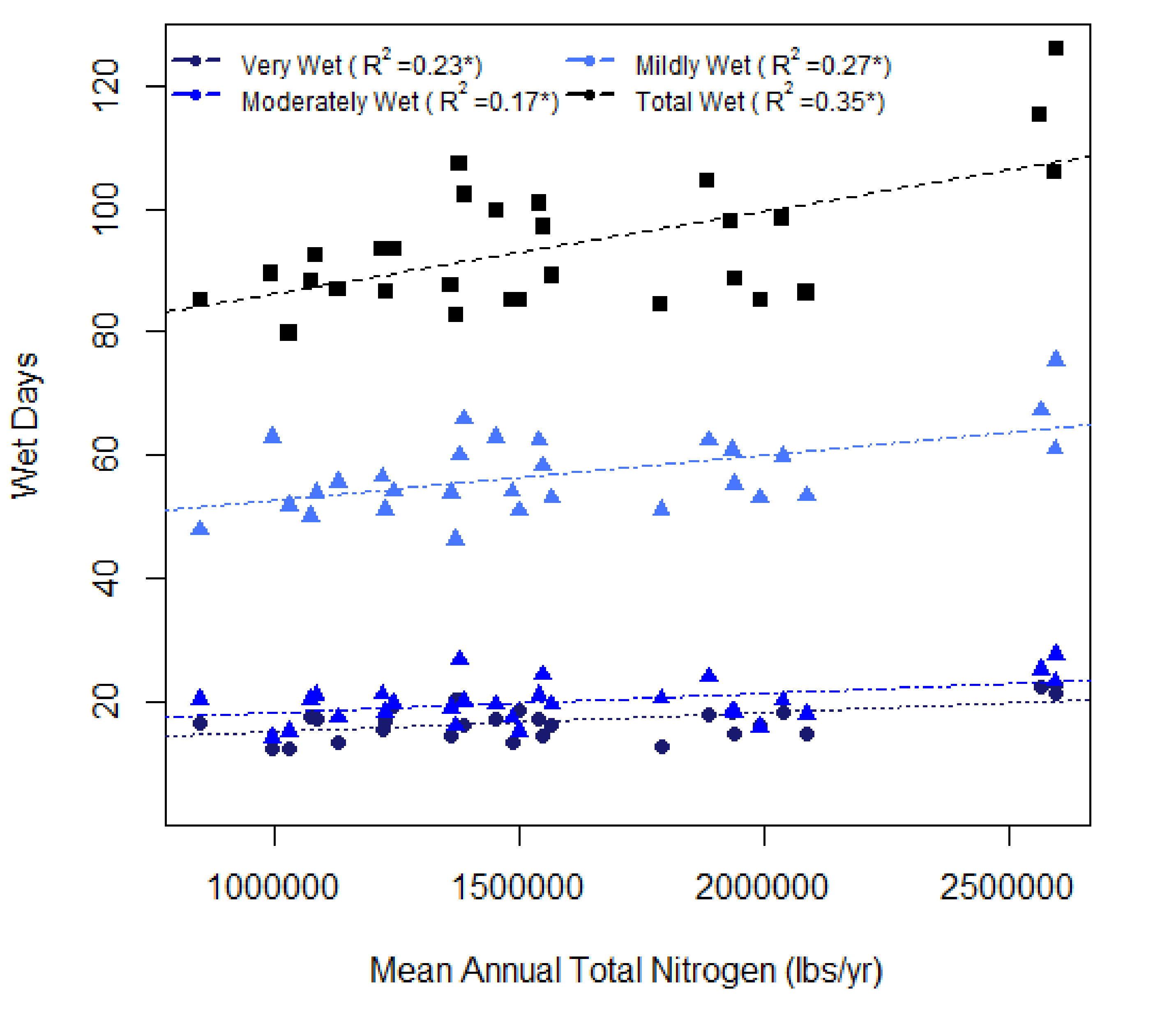


No Change



Less

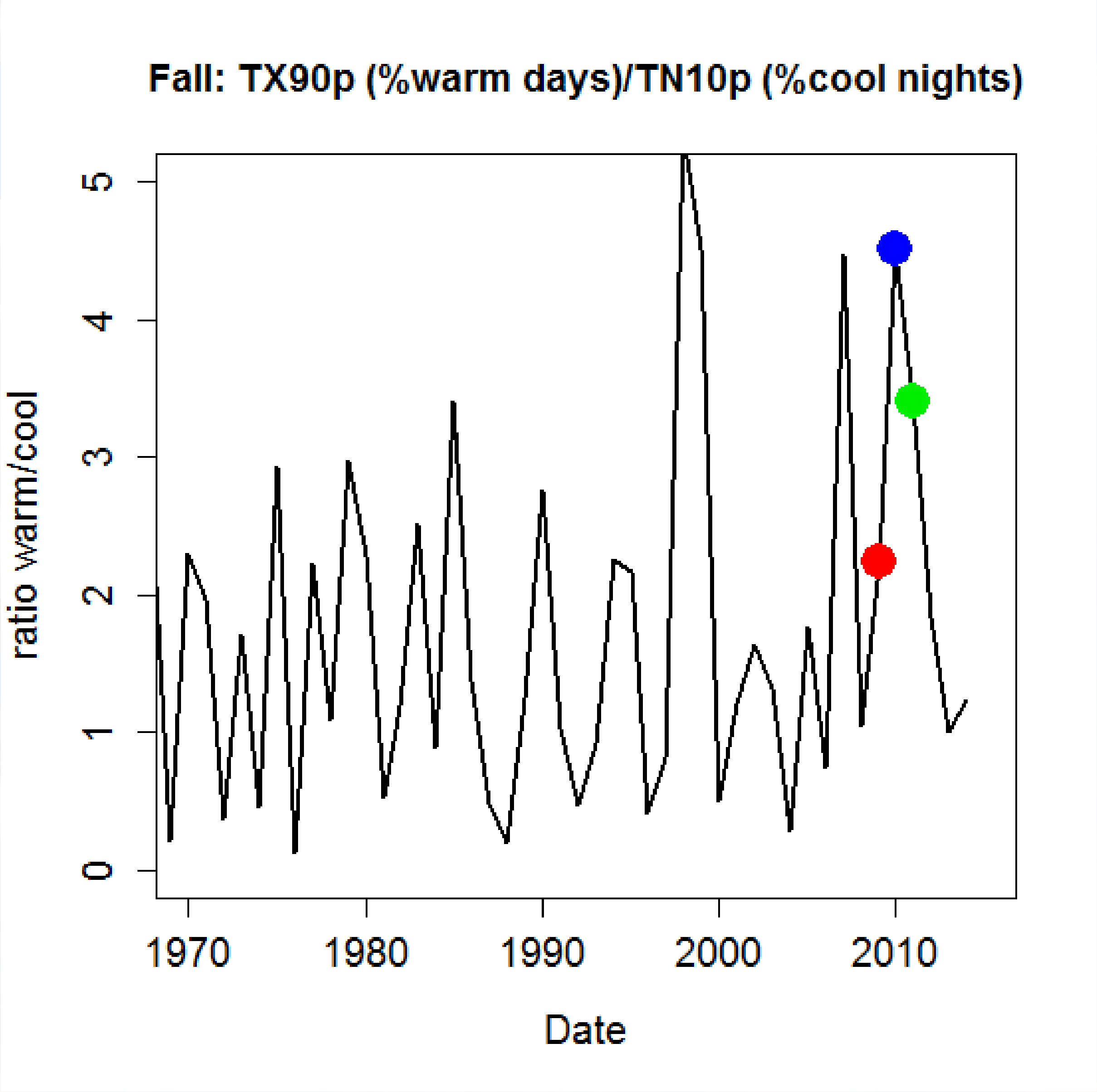
Wet Day Frequency & Nitrogen Loading in Patuxent River

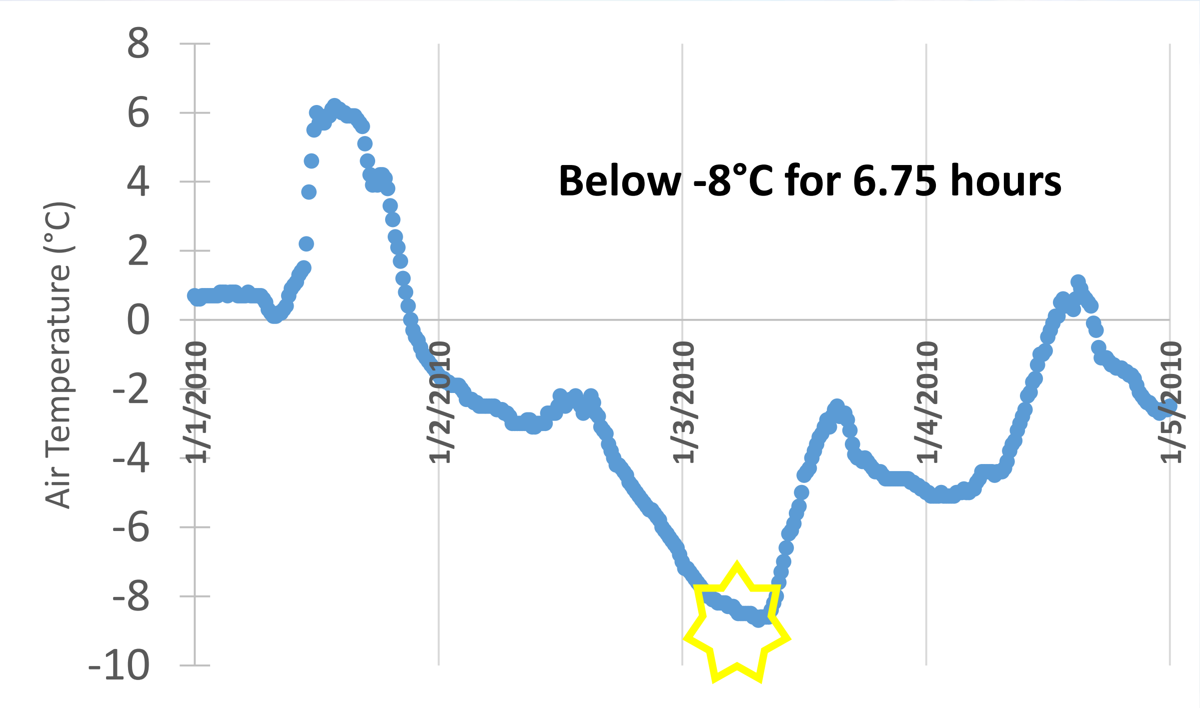


20 moderately wet days estimates a mean annual nitrogen load of 1,600,000 lbs/yr

MD DNR

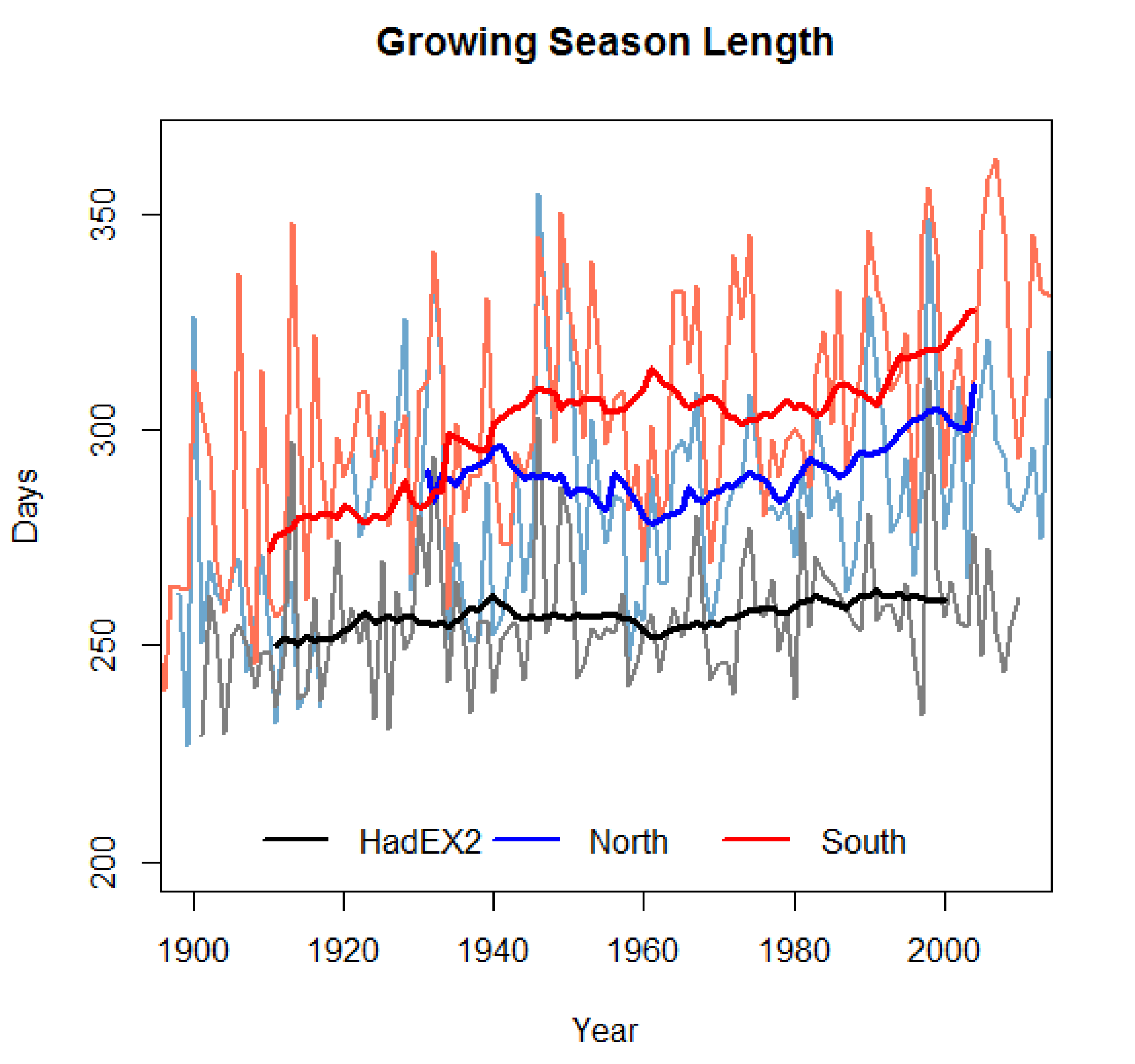
Warm autumns + cold snaps & brown pelican deaths





Linda Davidson/The Washington Post

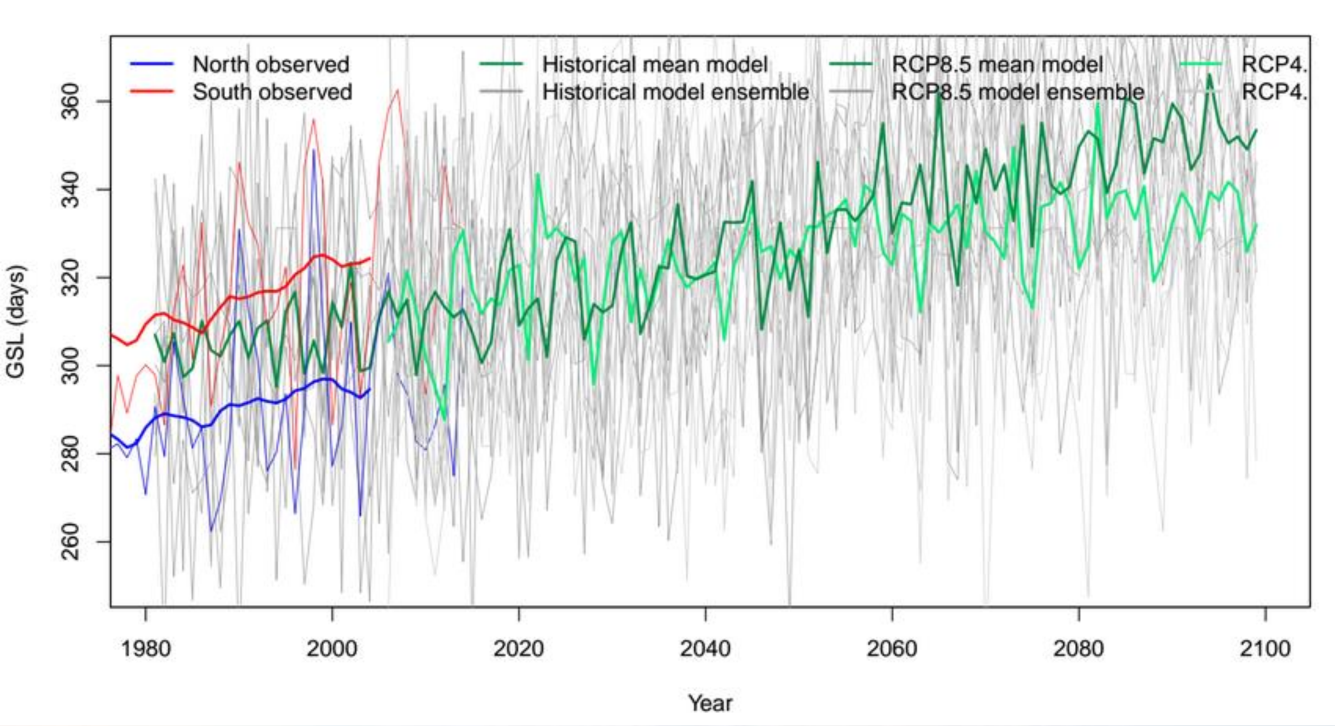
GSL: The length (in days) that wheat could grow.



The Growing Season has gotten **longer**

North: +1.7 days per decade

South: +4.4 days per decade



Summary

- % of warm summer days and nights has increased
  - Relationship to major SAV diebacks
- Annual Precipitation has increased
  - More very wet days and less mildly wet days
  - Wet day frequency linked to TN in Patuxent
- Tendency to get mild autumns
  - Cold variability can threaten cold snap events

- Climate indices have ecological applications to inform management strategies

Climate Change in Chesapeake Bay:
A gaze into the scientific process

SciencePensieve.org

Acknowledgements

Innovation for a better future

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

Chesapeake Bay
National Estuarine Research Reserve
Maryland

WILLIAM & MARY
VIMS
VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE

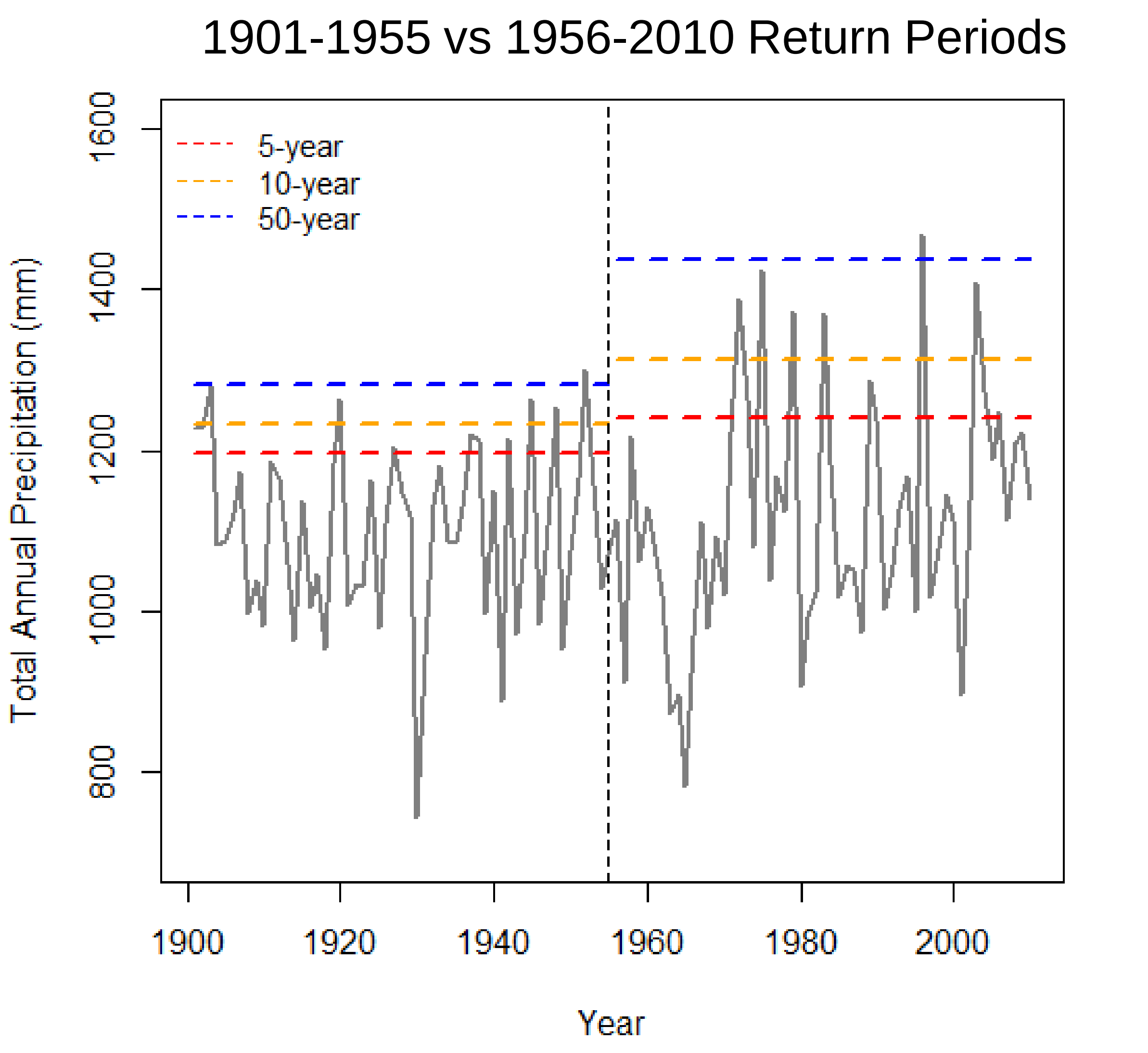
Chesapeake Bay National Estuarine Research Reserve

CINAR
Cooperative Institute for the North Atlantic Region

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

NCCOS
NOAA

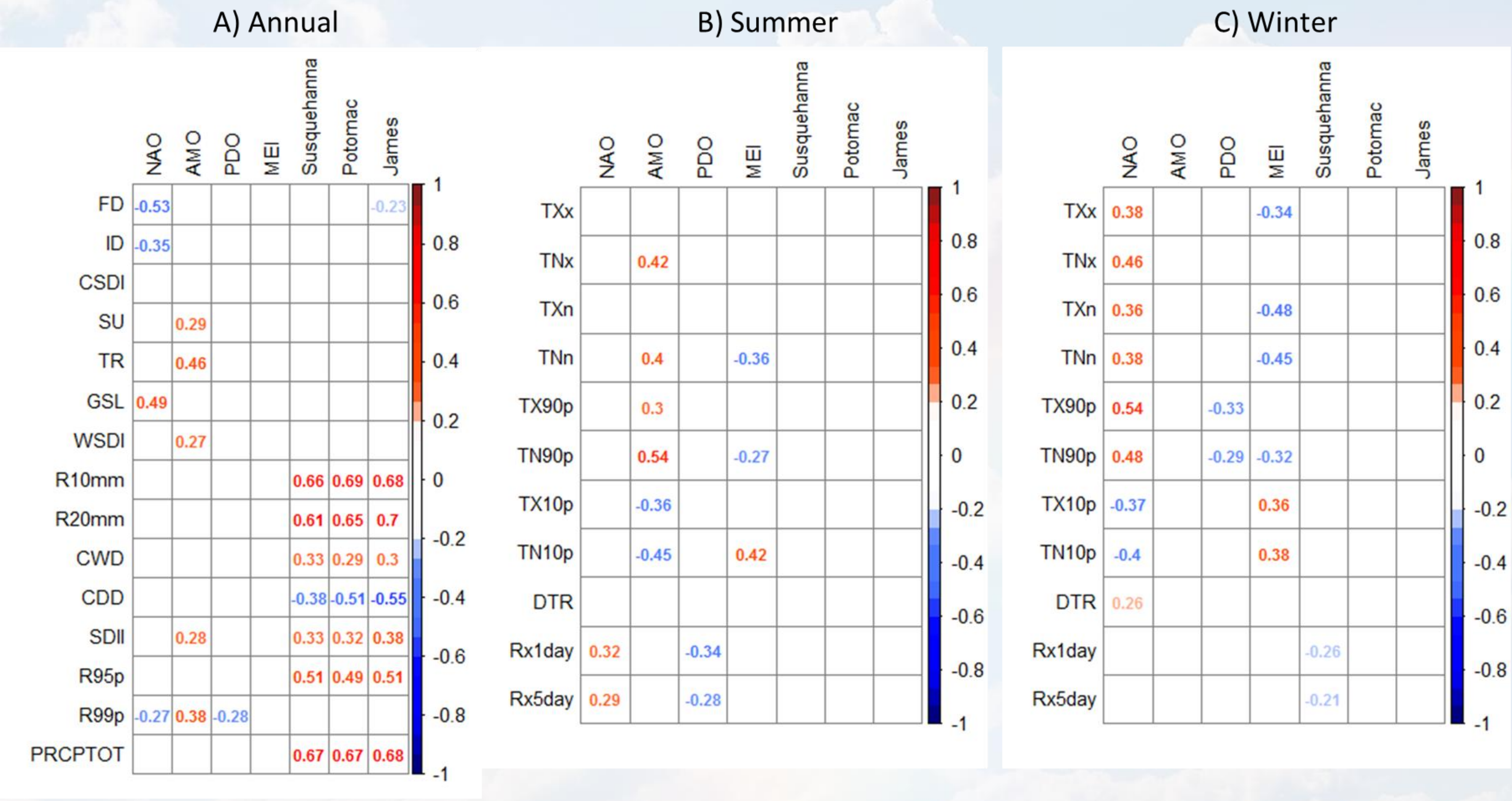
Initial Work: Return Periods

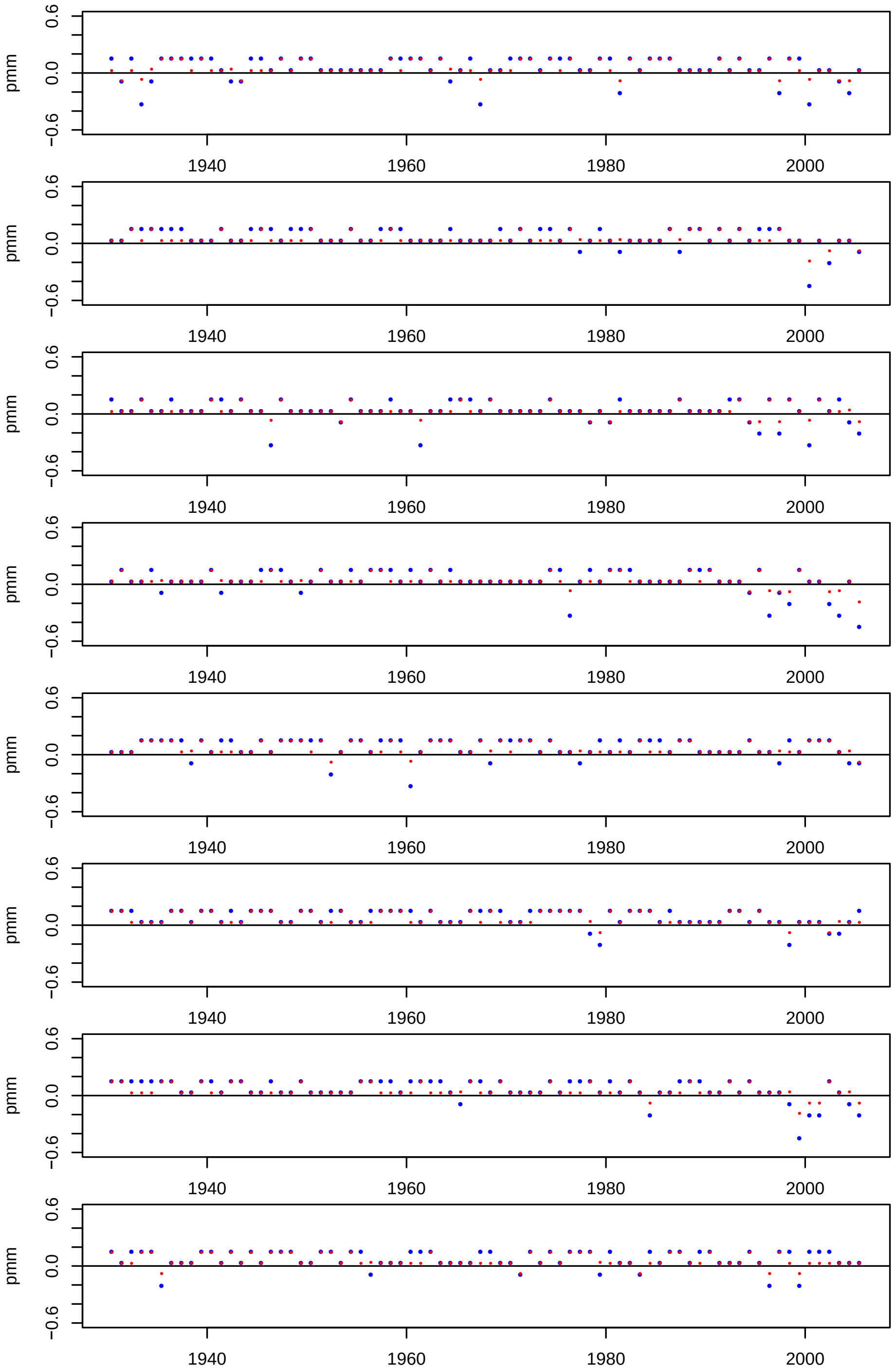


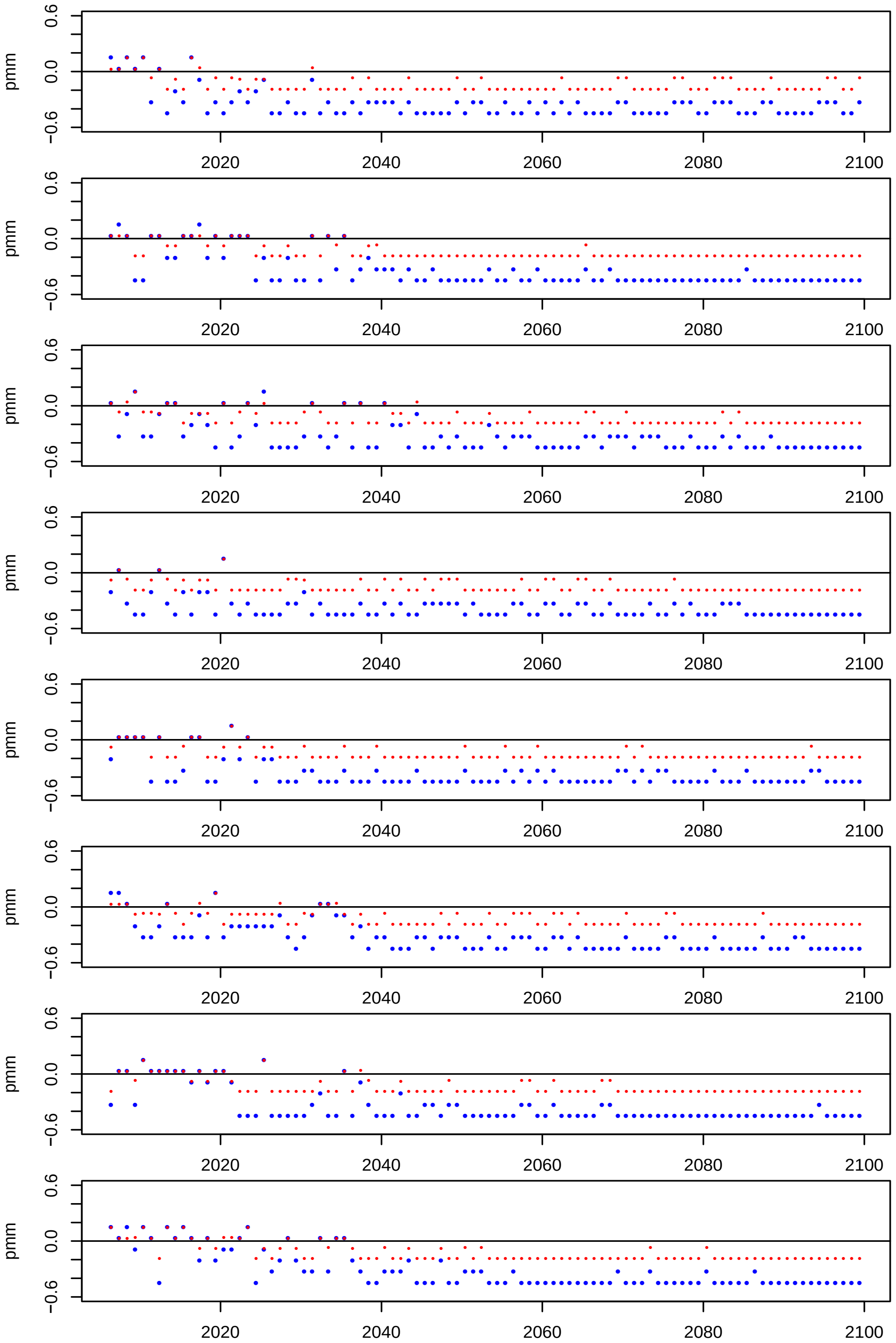
50-year → 7.4-year

50-year → +6.2 inches

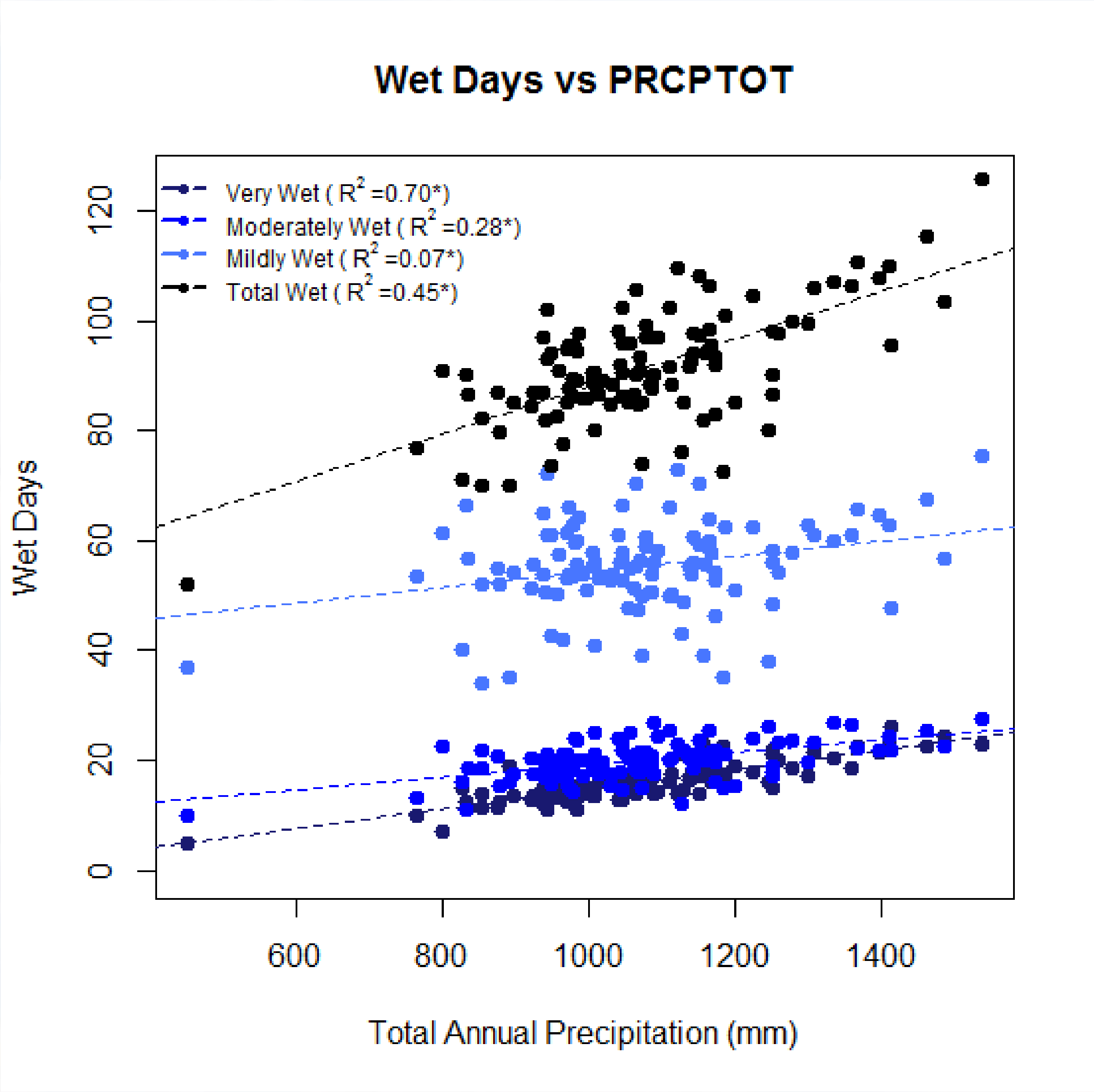
3.6×10^{12} US Gallons
or
5 million Olympic pools
Or 20% the volume if CB!


A) Annual
B) Summer
C) Winter
NAO
AMO
PDO
MEI
Susquehanna
Potomac
James
FD -0.53 -0.23
ID -0.35
CSDI
SU 0.29
TR 0.46
GSL 0.49
WSDI 0.27
R10mm 0.66 0.69 0.68
R20mm 0.61 0.65 0.7
CWD 0.33 0.29 0.3
CDD -0.38 -0.51 -0.55
SDII 0.28 0.33 0.32 0.38
R95p 0.51 0.49 0.51
R99p -0.27 0.38 -0.28
PRCPTOT 0.67 0.67 0.68
TXx
TNx 0.42
TXn
TNn 0.4 -0.36
TX90p 0.3
TN90p 0.54 -0.27
TX10p -0.36
TN10p -0.45 0.42
DTR
Rx1day 0.32 -0.34
Rx5day 0.29 -0.28
TXx 0.38 -0.34
TNx 0.46
TXn 0.36 -0.48
TNn 0.38 -0.45
TX90p 0.54 -0.33
TN90p 0.48 -0.29 -0.32
TX10p -0.37 0.36
TN10p -0.4 0.38
DTR 0.26
Rx1day -0.26
Rx5day -0.21
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

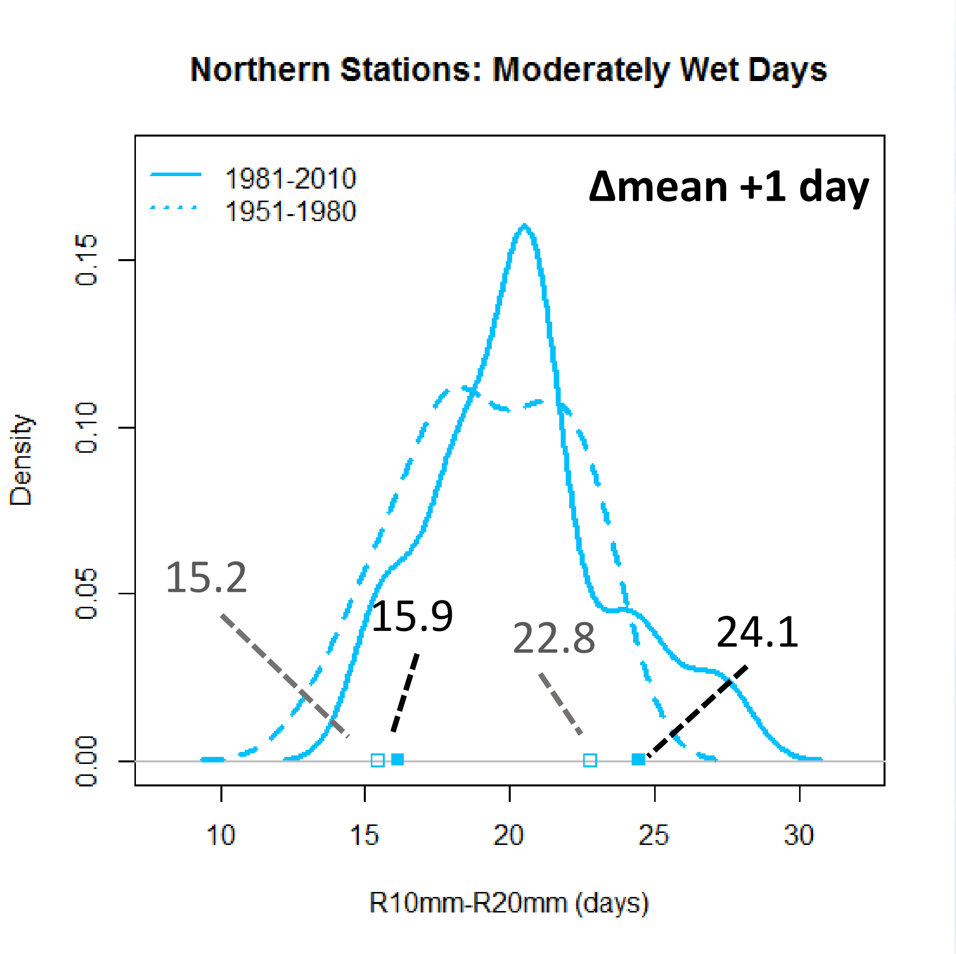

pmm
0.6
0.0
-0.6
1940
1960
1980
2000


pmm
0.6
0.0
-0.6
2020
2040
2060
2080
2100

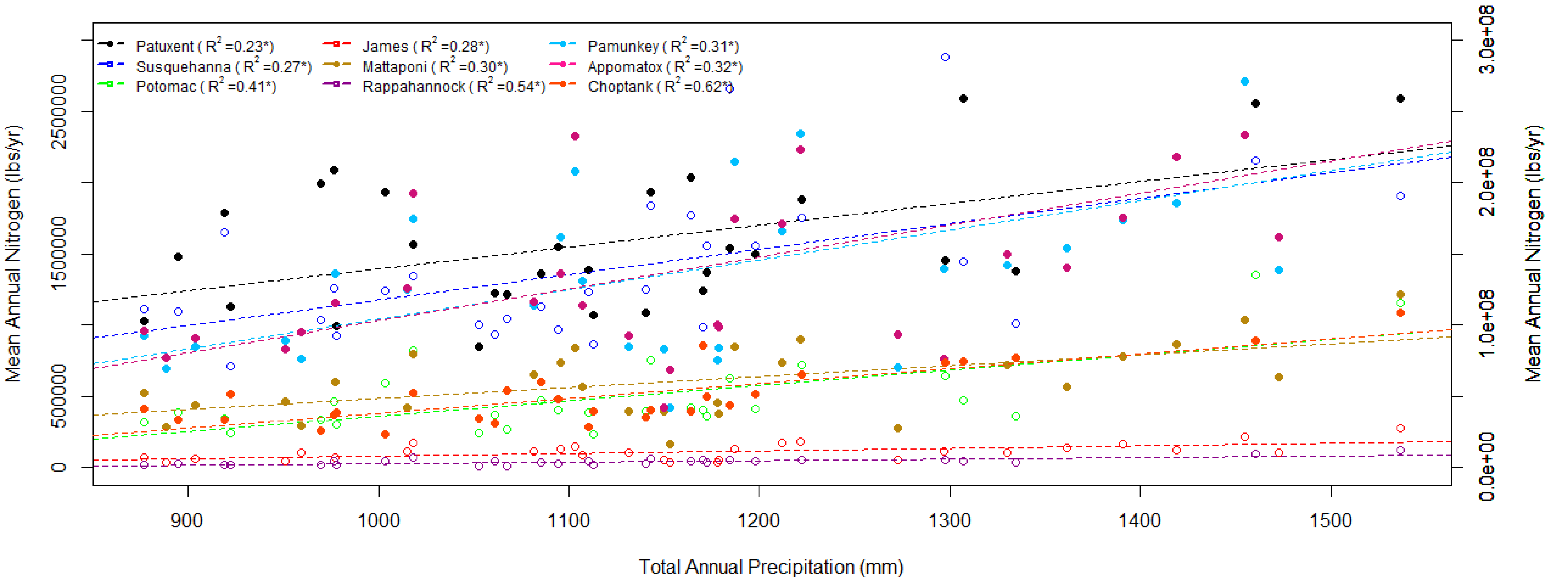
Wet Day Frequency vs Annual Precipitation

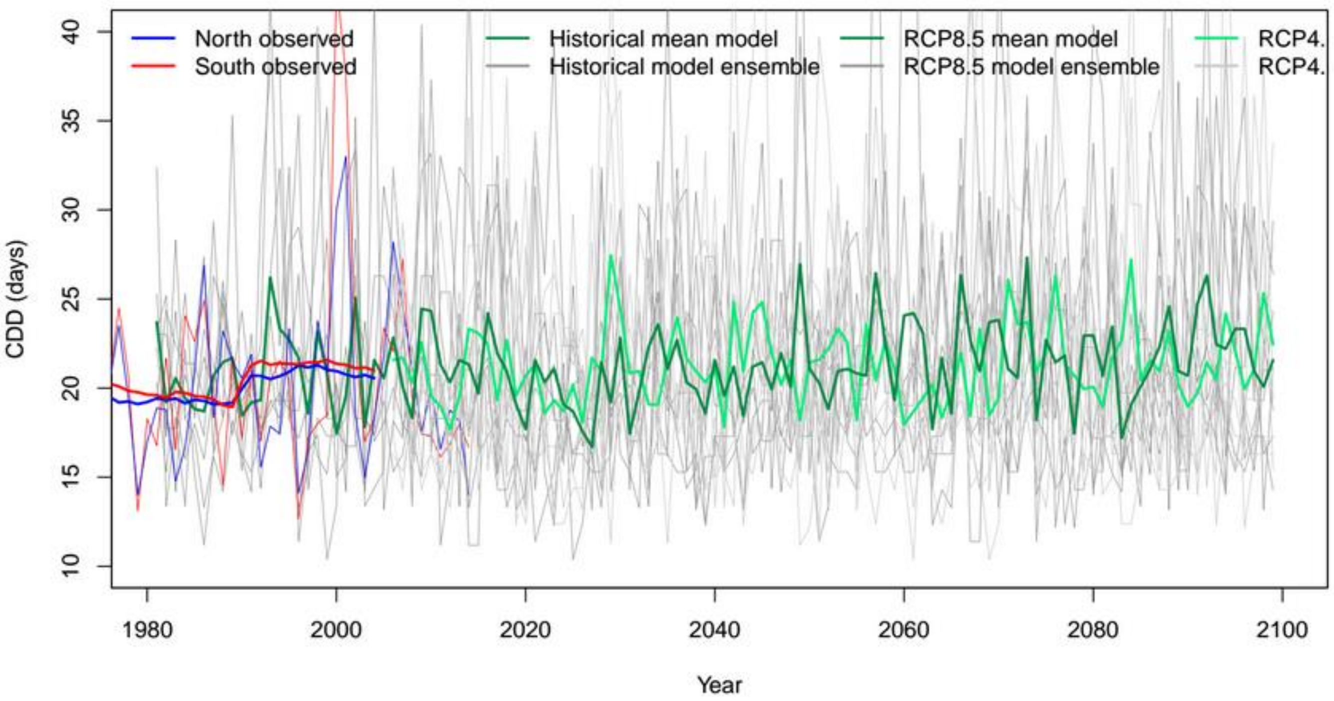


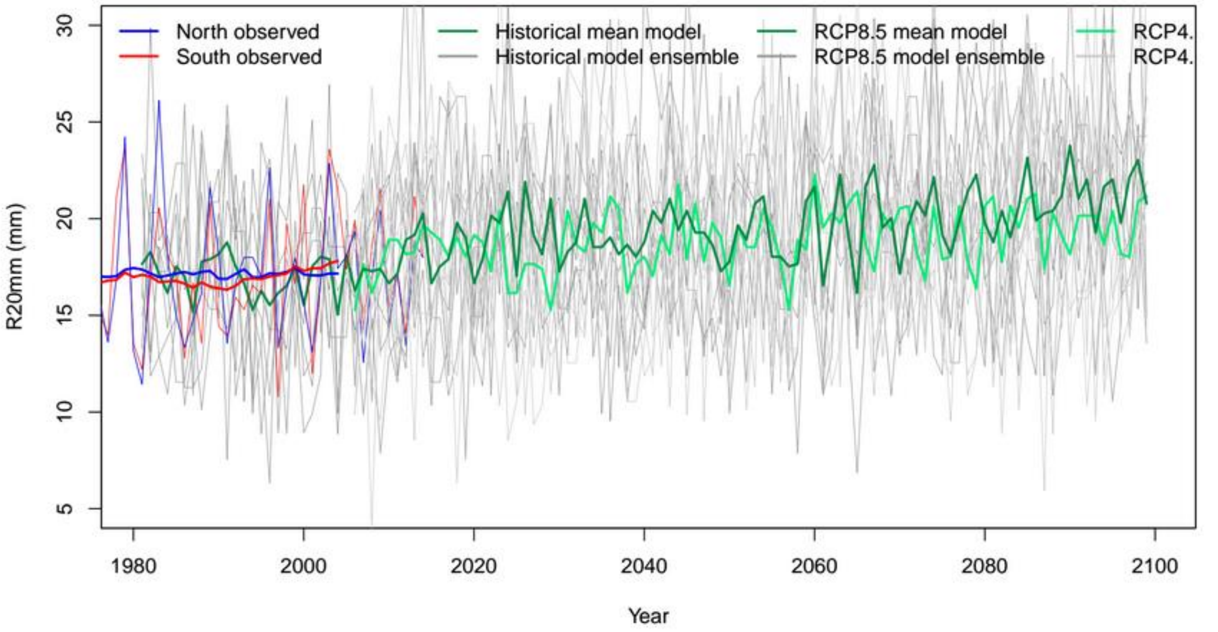
If we get 1071 mm precipitation, we can estimate to have had 20 moderately wet days

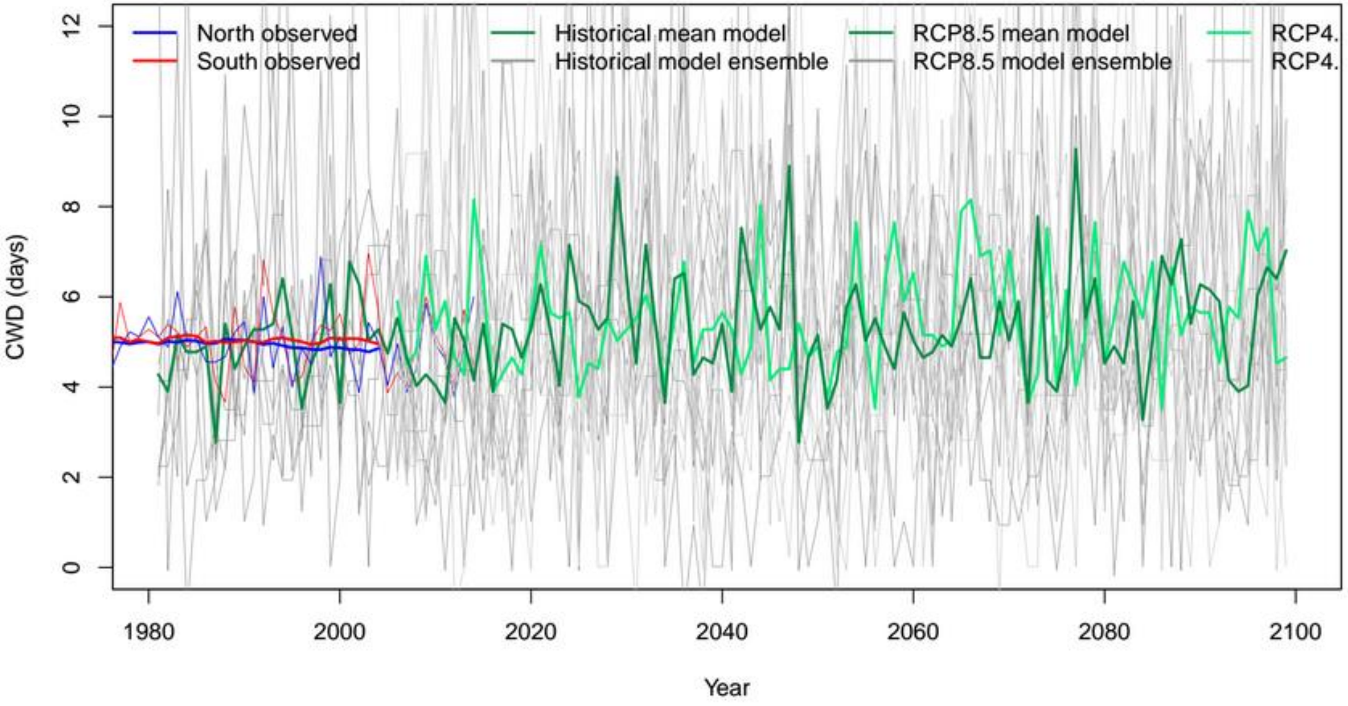


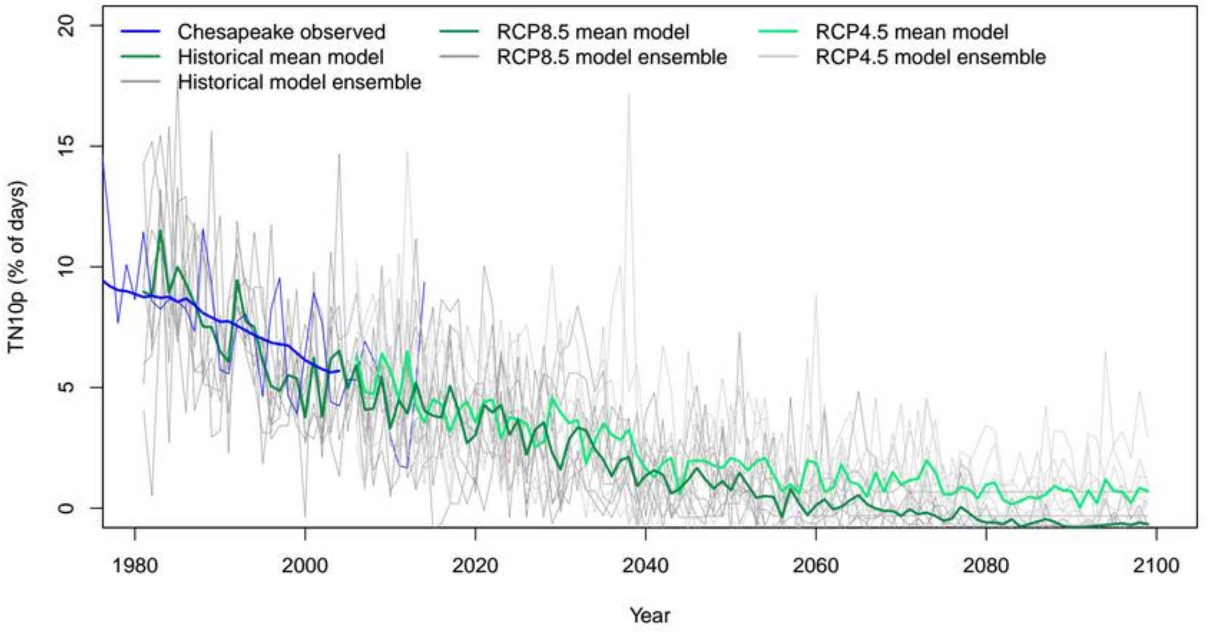
Total Nitrogen vs Precipitation from 1985-2013



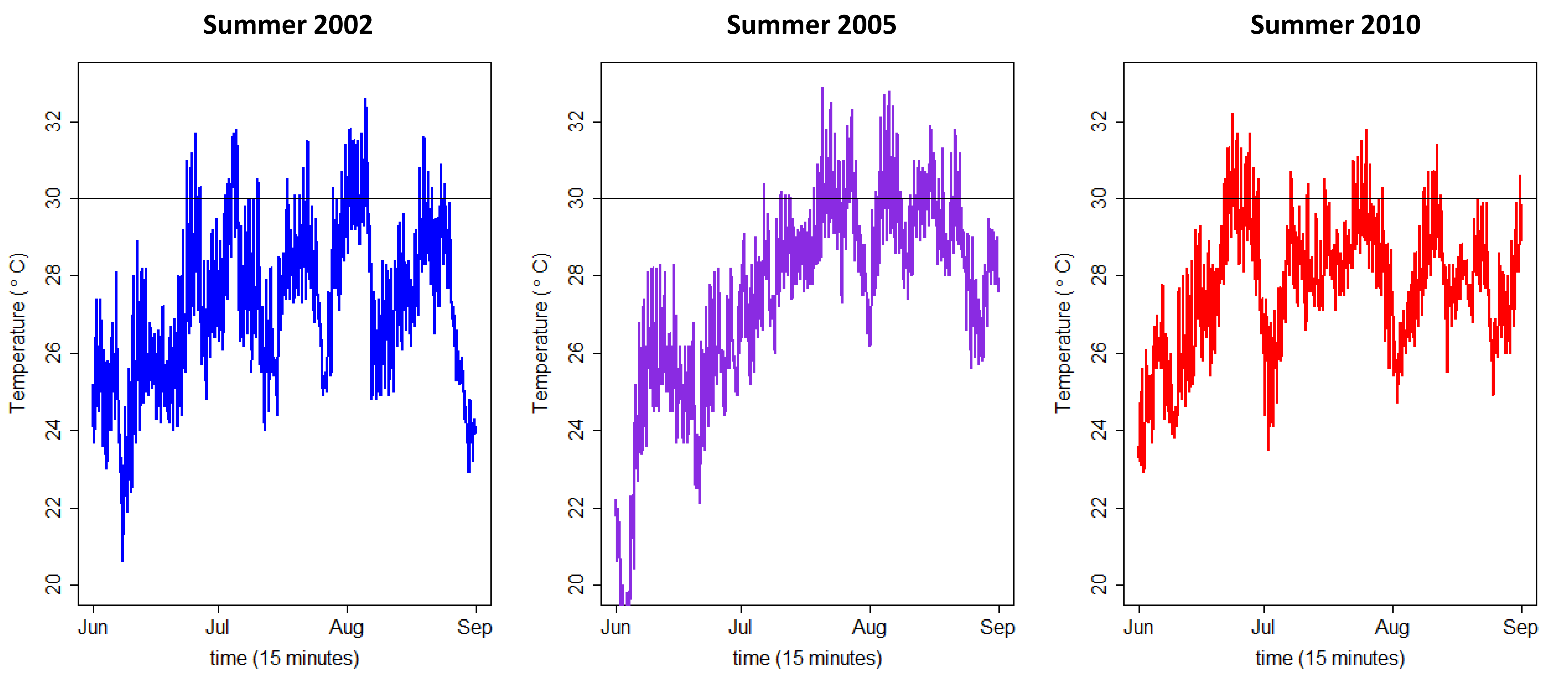

North observed
South observed
Historical mean model
Historical model ensemble
RCP8.5 mean model
RCP8.5 model ensemble
RCP4.
RCP4.
CDD (days)
Year


North observed
South observed
Historical mean model
Historical model ensemble
RCP8.5 mean model
RCP8.5 model ensemble
RCP4.
RCP4.
R20mm (mm)
Year


North observed
South observed
Historical mean model
Historical model ensemble
RCP8.5 mean model
RCP8.5 model ensemble
RCP4.
RCP4.
CWD (days)
Year


Chesapeake observed
Historical mean model
Historical model ensemble
RCP8.5 mean model
RCP8.5 model ensemble
RCP4.5 mean model
RCP4.5 model ensemble
TN10p (% of days)
Year

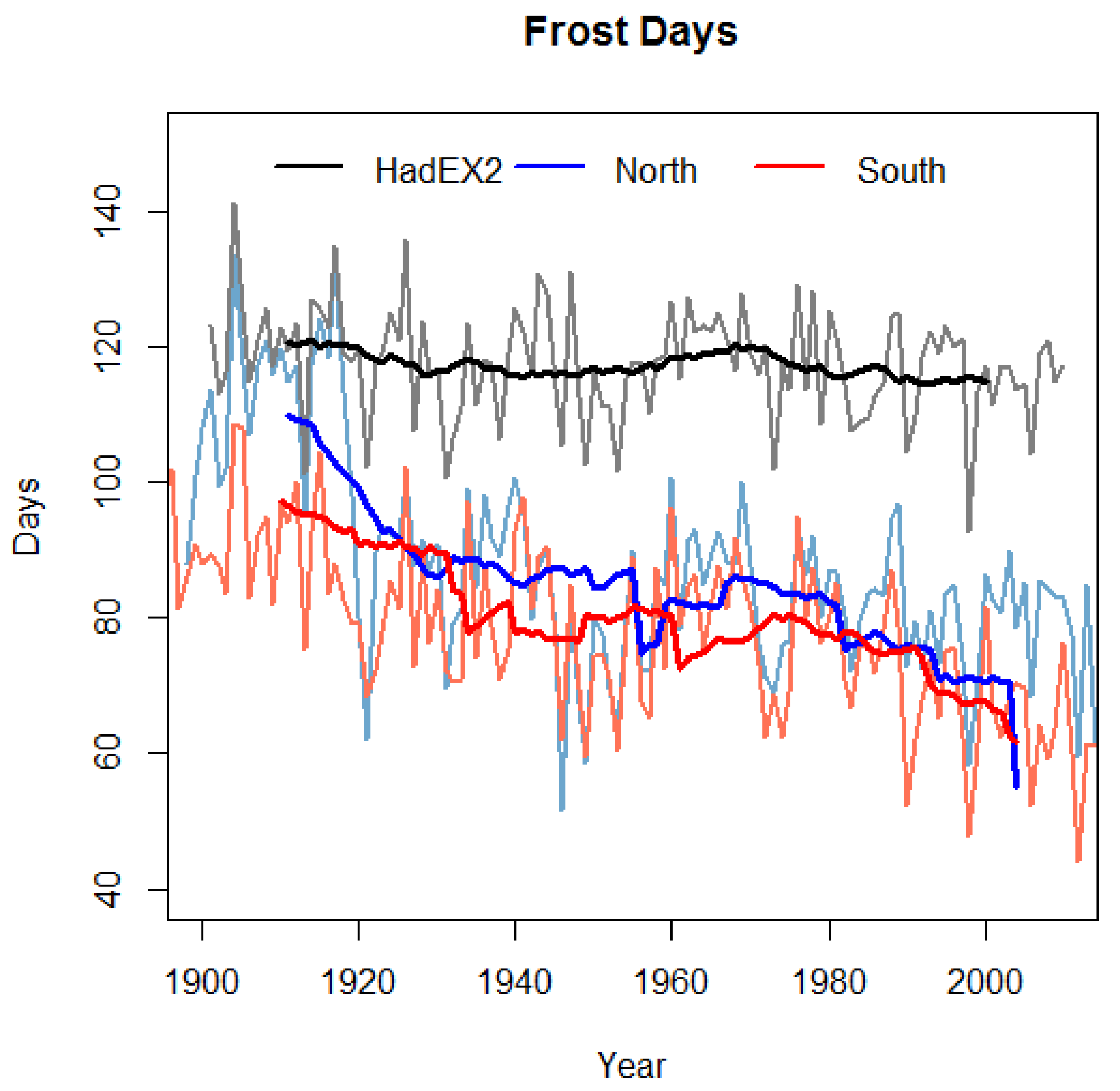
SAV Diebacks and Warm Temperatures



Submerged Aquatic Vegetation: The Highs and Lows

Exceedances of 30°C at Goodwin Islands			
Month (% of exceedances)		**Year** (% of exceedances)	
Jan	0.0%	1998	2.4%
Feb	0.0%	1999	10.2%
Mar	0.0%	2000	0.4%
Apr	0.0%	2001	3.2%
May	0.0%	**2002**	**12.4%**
Jun	**8.7%**	2003	3.4%
Jul	**46.4%**	2004	2.6%
Aug	**44.9%**	**2005**	**20.7%**
Sep	0.0%	2006	8.6%
Oct	0.0%	2007	5.8%
Nov	0.0%	2008	2.6%
Dec	0.0%	2009	1.3%
		2010	**10.6%**
		2011	7.2%
		2012	6.2%
		2013	2.5%
		2014	0.1%

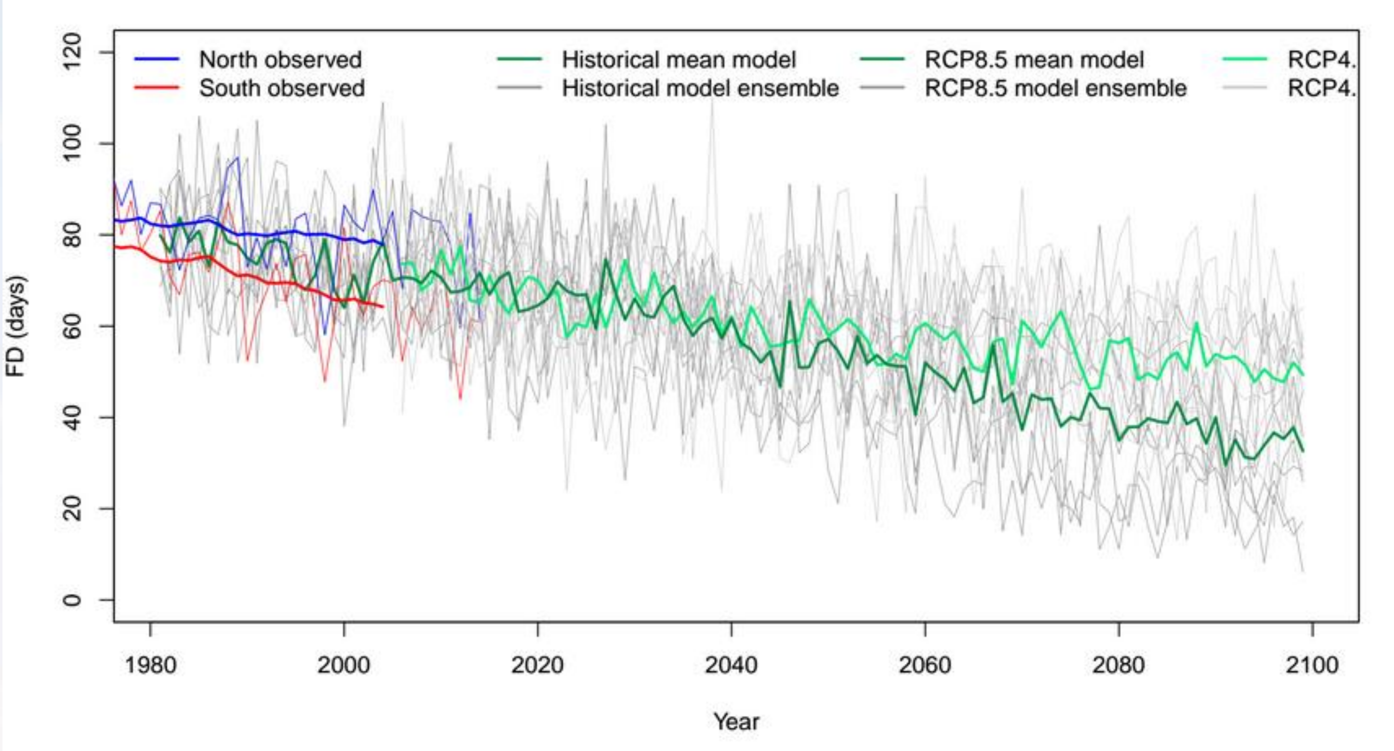
Frost Days: The amount of days each year when the coldest daily temperature is below freezing



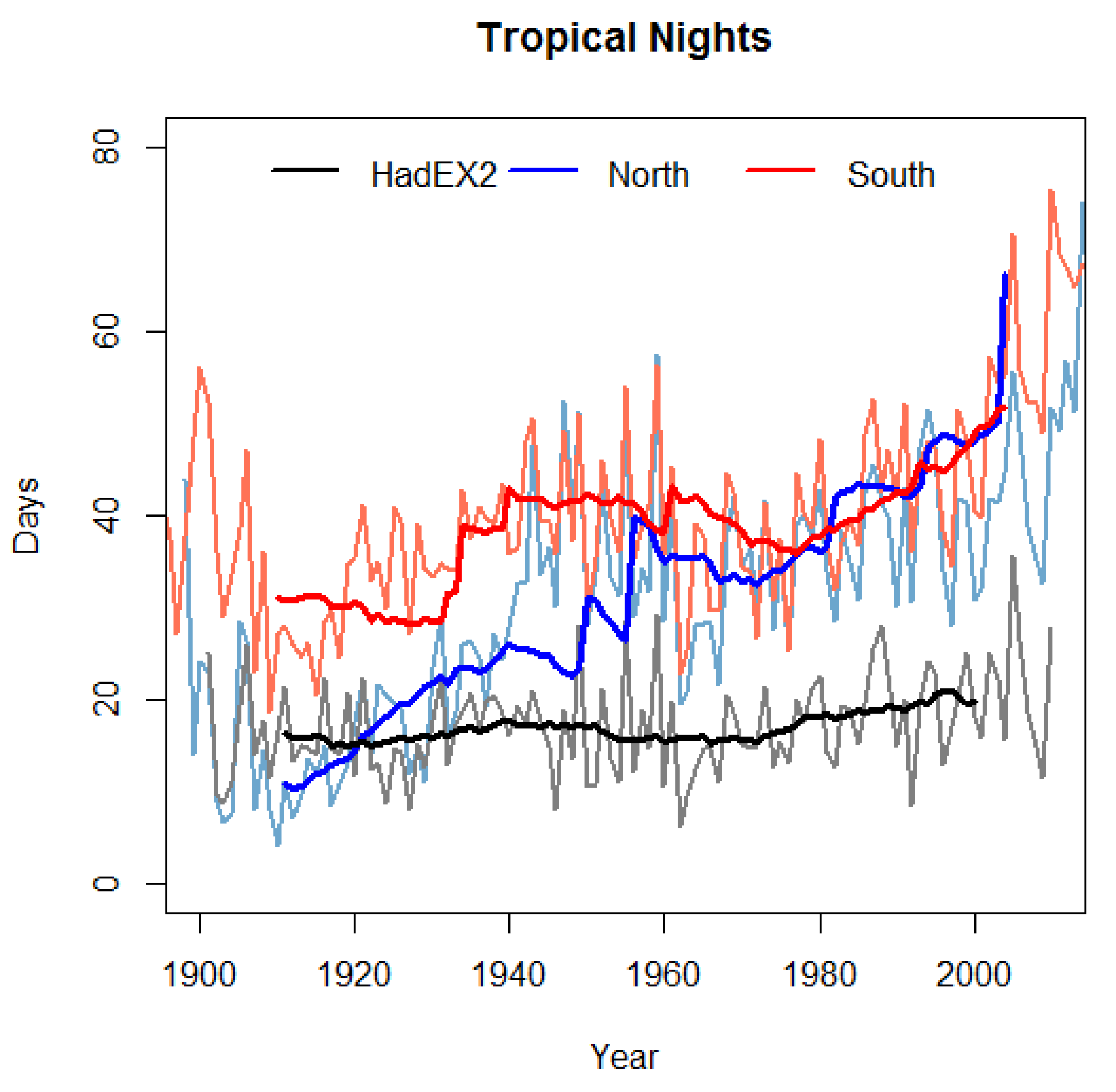
We have seen a **decrease** in the amount of frost days

North: -3.3 days per decade

South: -2.8 days per decade



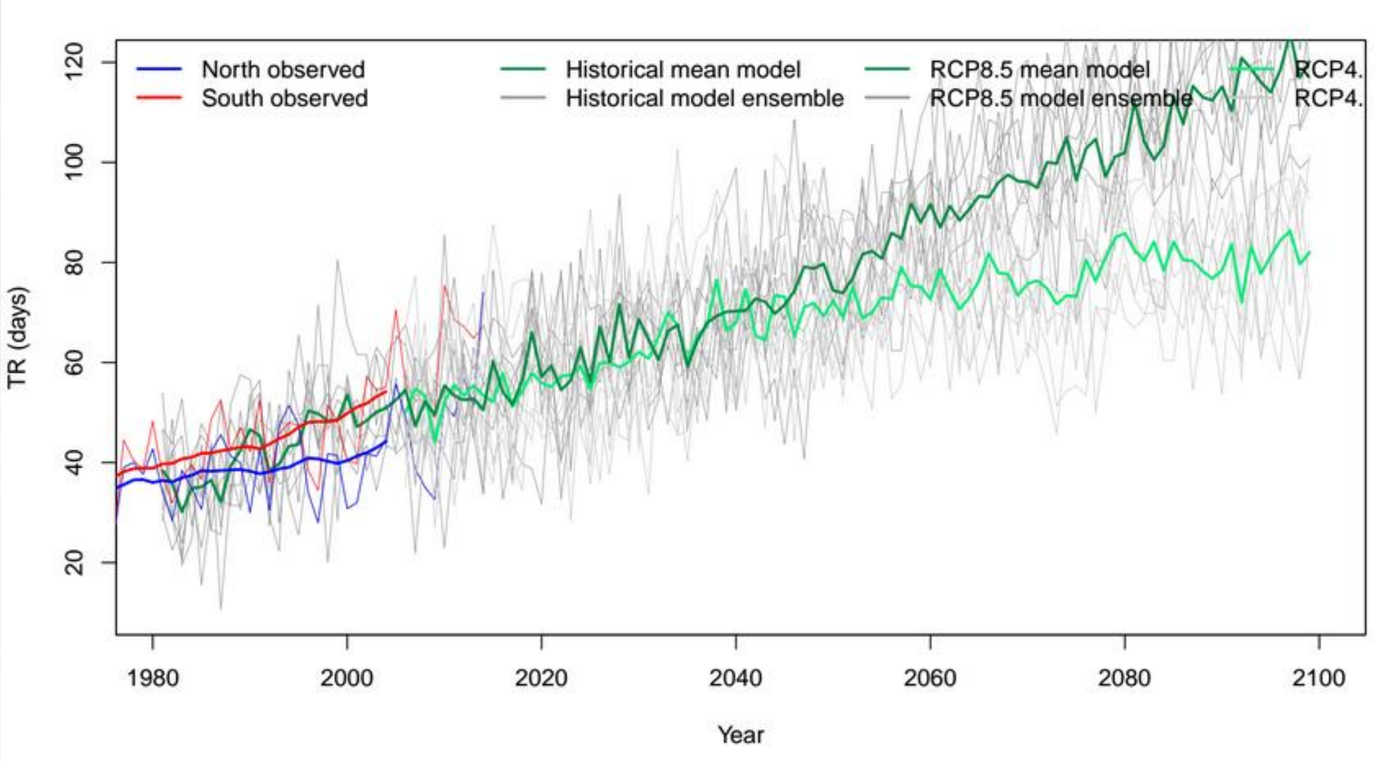
Tropical Nights: The amount of days each year when the coldest daily temperature is > 20°C (68°F)



The amount of warm "summer" nights have **increased**

North: +4.1 days per decade

South: +2.0 days per decade



R95p: The "extra" rain wet get each year, defined as the amount of rain >95th percentile.

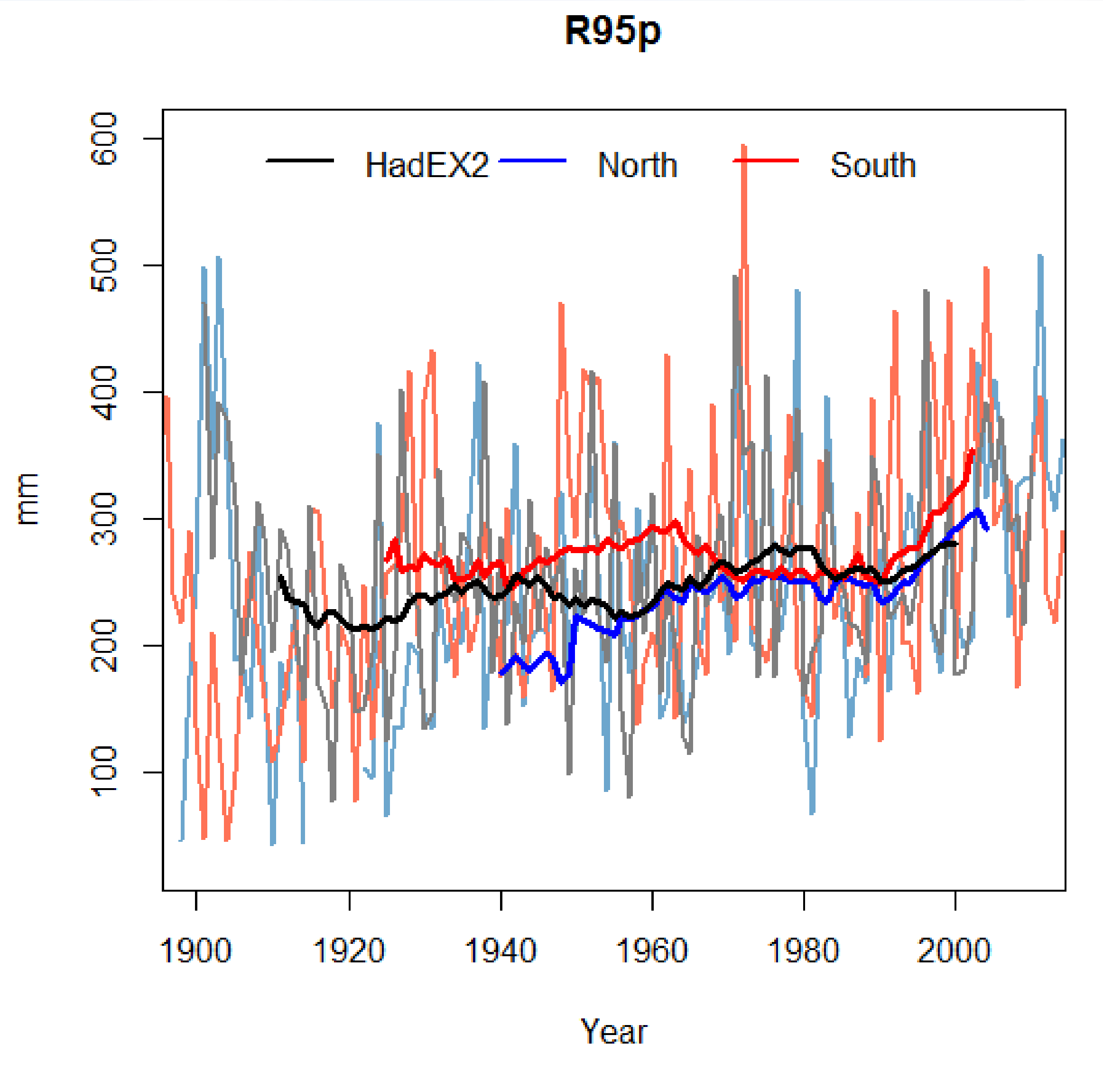
We have seen **more precipitation**

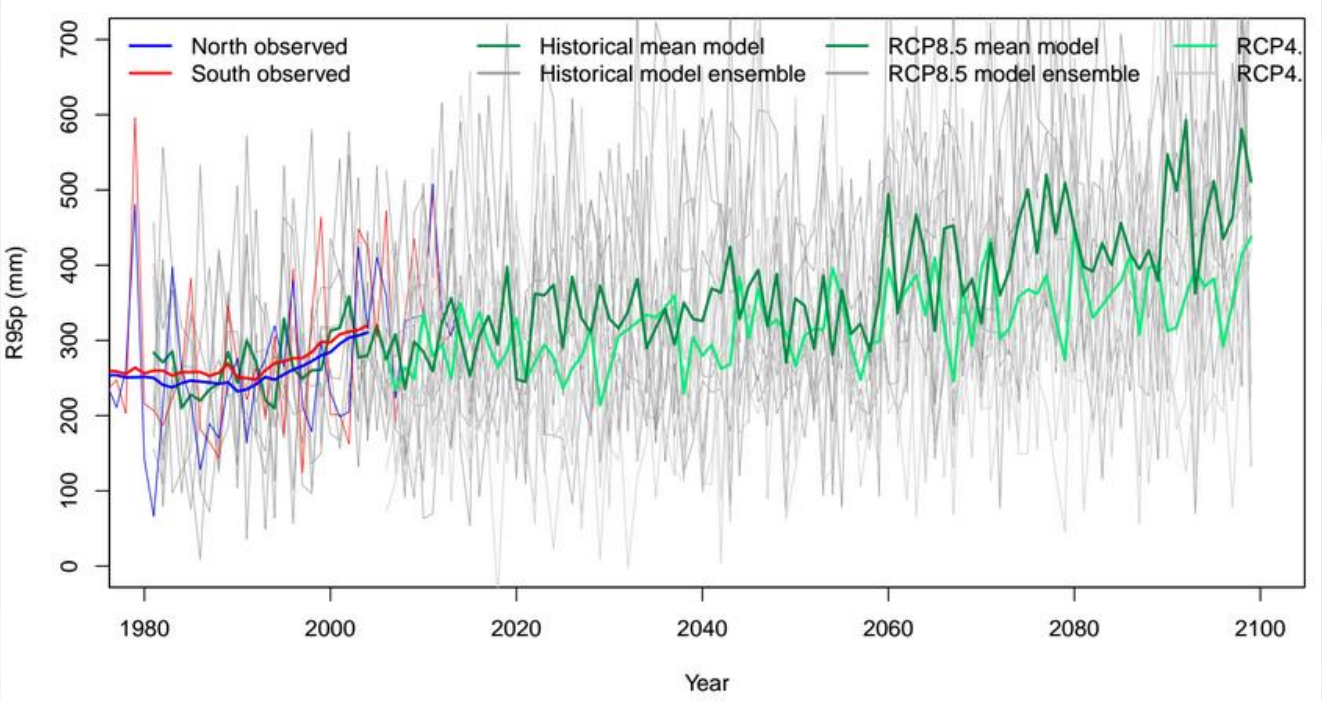
North: +14.8 mm per decade

South: +2.8 mm per decade

95th percentile in North: 16.1 mm (0.63 in)

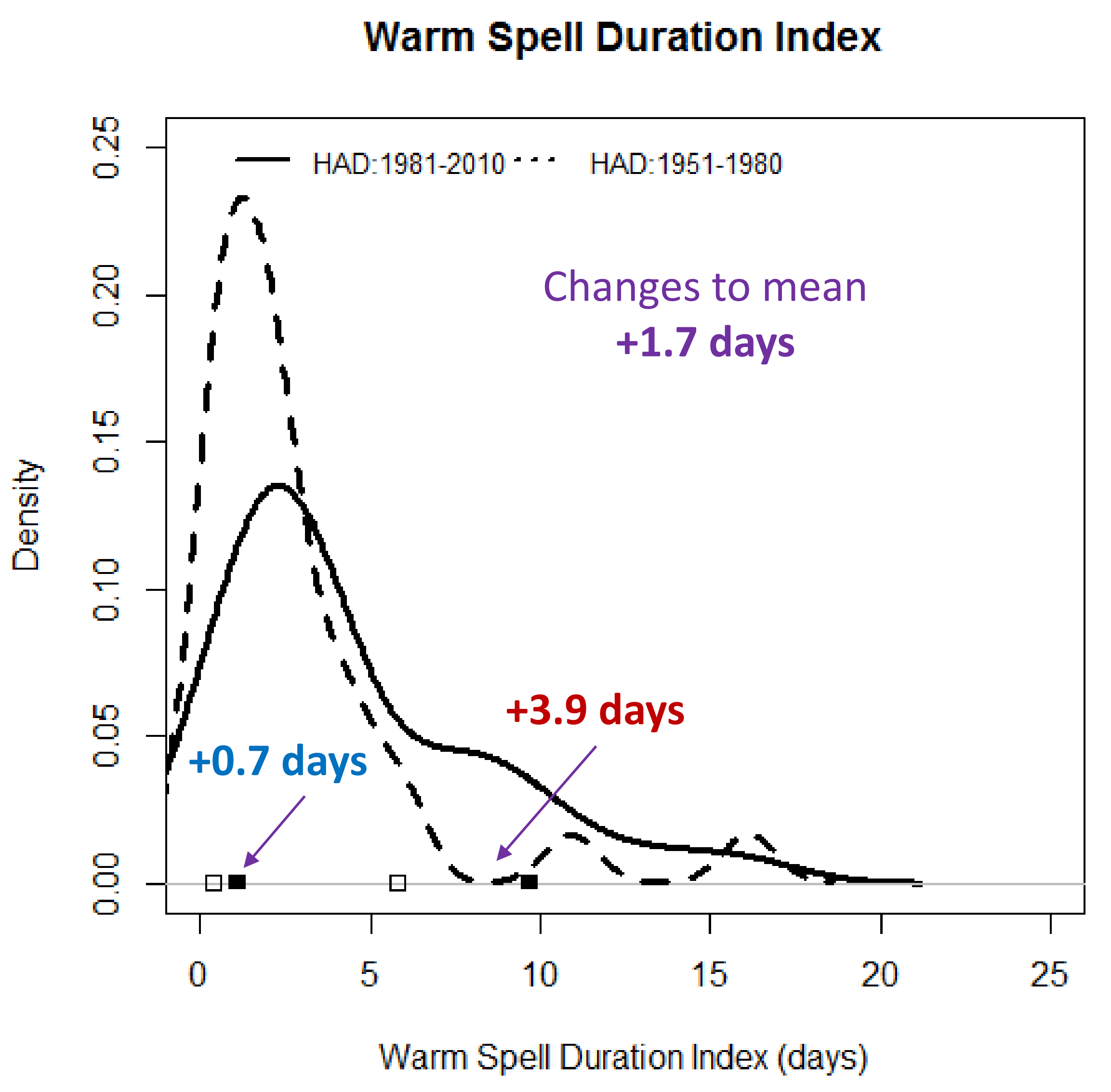
95th percentile in South: 16.9 mm (0.67 in)





Warm Spell Duration

The longest warm spell defined as at least 6 consecutive days that are hotter than 9 out of 10



Changes to 10th percentile

HadEX2: +0.7 days

Changes to 90th percentile

HadEX2: +3.9 days

Changes to mean

HadEX2: +1.7 days

Significantly Different (p-value <0.05)

Other items of Interest (You wanted numbers!)

	INDEX	Δmean			
		HadEX2	GHCNdex	North	South
Annual Temperature	Frost Days	-3	-5.8	-2.7	-9.3
	Summer Days	-2.6	0.7	2.5	6.3
	Icing Days	0.2	-2.1	-1.8	-0.9
	Tropical Nights	3.5	3.9	4.6	9.1
	Growing Season	8	13.8	12.8	14.1
	Warm Spells	1.7	1.8	2.6	2.3
	Cold Spells	0	-0.3	0	-0.6
Annual Precipitation	R10mm	1.6	1.5	2	-0.2
	R20mm	1.3	1.4	1	0
	CDD	-0.7	-0.3	0.6	0.7
	CWD	0.2	0.1	0.1	0.1
	R95p	14.6	30.8	7.8	-12.7
	R99p	-8.6	2.6	0	-2.5
	PRCPTOT	41	51	40	-13

This is the **mean change** from 1951-1980 to 1981-2010

These 30 year periods are **climate normals** used to assess mean weather.

(Ex. “today is 2° warmer than the average for October”)

Where highlighted, the change was statistically significant.

Other items of Interest (You wanted numbers!)

Index	Season	Δmean (1951-1980 to 1981-2010) HadEX2	GHCNdex	North	South
Rx5day (mm) the most rain we hot over 5 days	Winter	0.6	-0.5	4.2	1.2
	Spring	4.1	1.8	3.7	0.4
	Summer	-1.6	-0.9	-9.2	1.2
	Fall	0.6	1.3	2.6	-0.2
TXx (°C) Warmest Temperature	Winter	1.3	1.1	1.4	1.2
	Spring	-0.1	0	0.5	0.3
	Summer	-0.1	0.2	0.7	0.3
	Fall	0.2	0.4	0.2	-0.1
TNn (°C) Coldest Temperature	Winter	1.7	1.8	1.2	1.8
	Spring	0.7	0.7	0	1
	Summer	1.2	1	0.2	1
	Fall	1.1	1.5	0.8	1.6
TN10p (%days that were really cold)	Winter	-4	-5	-4.9	-4.9
	Spring	-1.2	-1.3	1.3	-1.6
	Summer	-3.6	-2.7	-2.2	-2.3
	Fall	-1.4	-3	-0.5	-3.4
TX90p (%days that were really warm)	Winter	2.6	2.4	2.4	1.8
	Spring	-1.4	-1.4	1.8	1.2
	Summer	0	0.9	2.4	2.1
	Fall	1.3	1.4	2	1.9

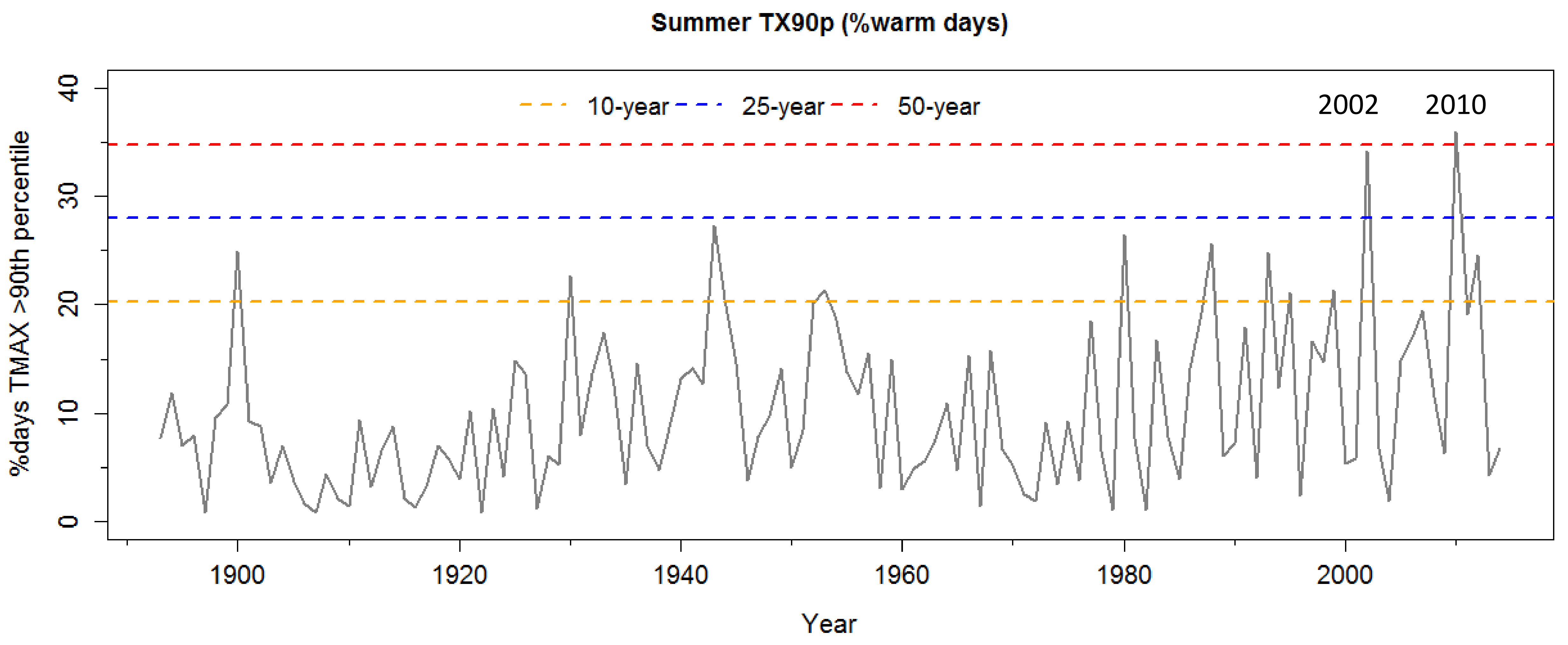
This is the **mean change** from 1951-1980 to 1981-2010 for seasonal indices

These 30 year periods are **climate normals** used to assess mean weather.

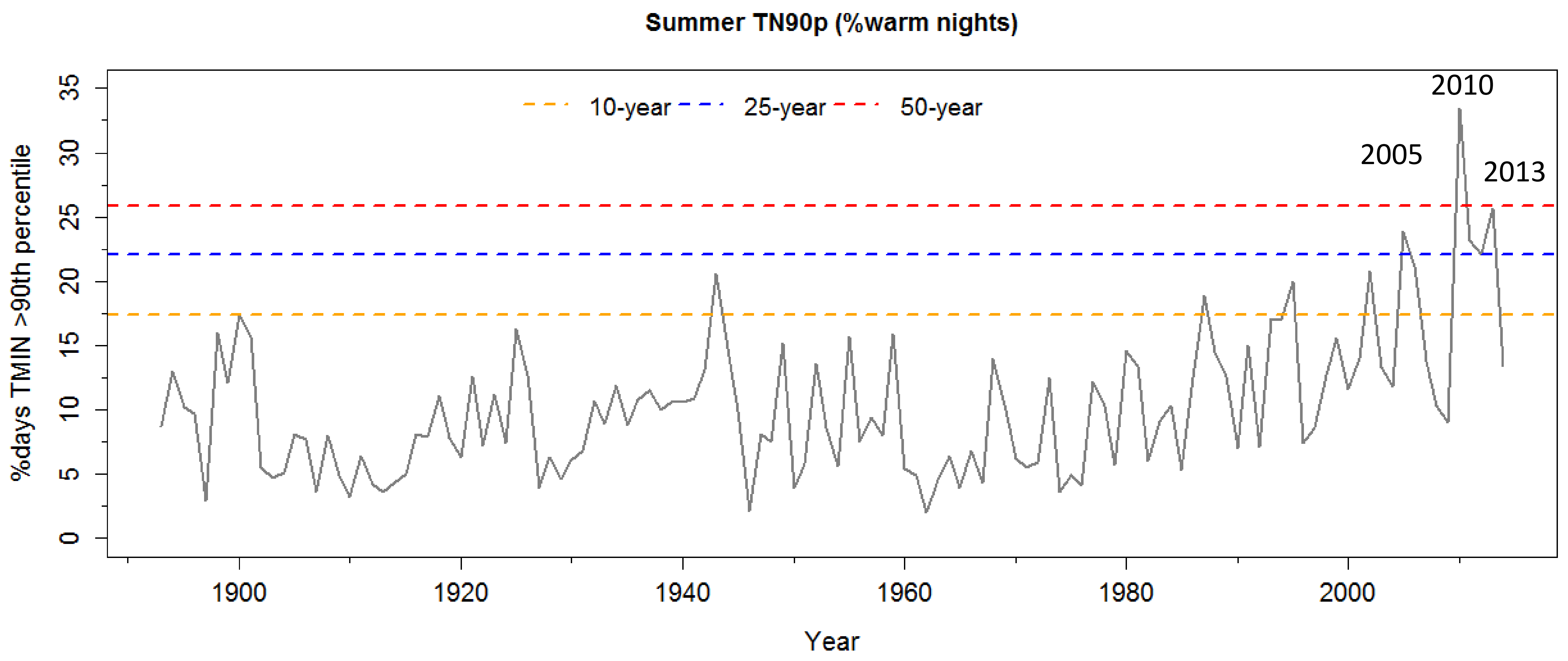
(Ex. "today is 2° warmer than the average for October")

Where highlighted, the change was statistically significant.

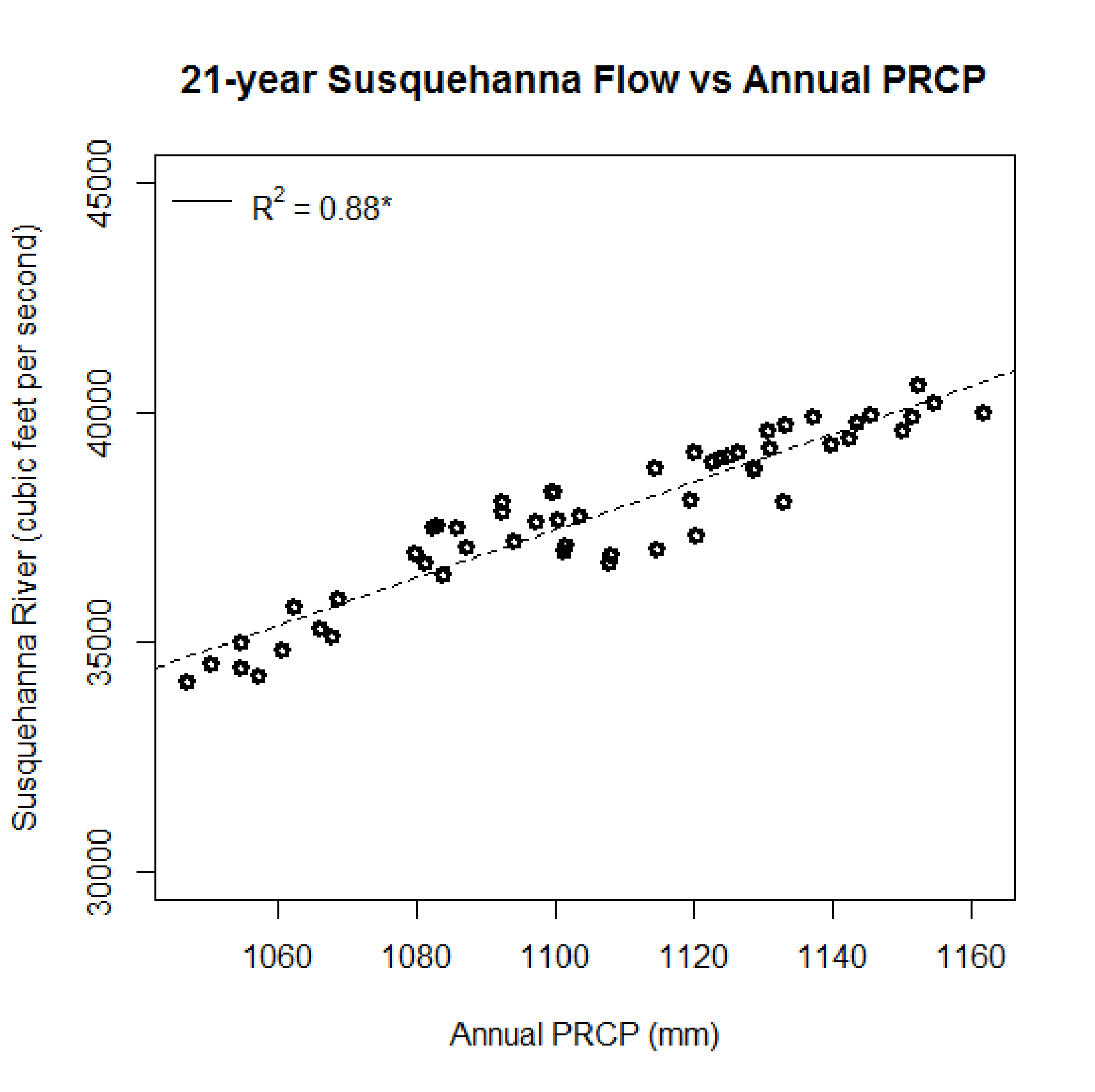
Recurrence Intervals of Warm Summer Days

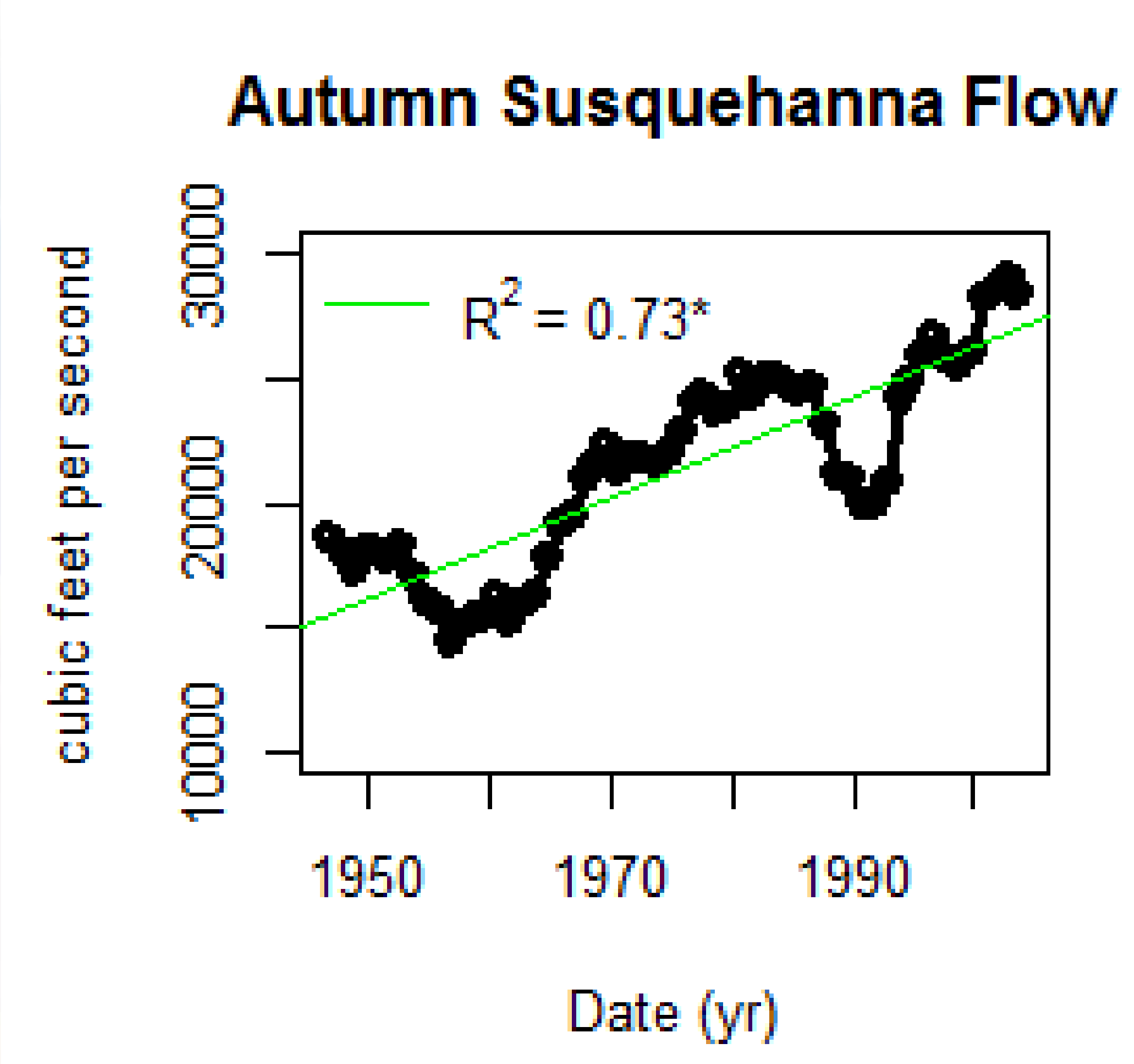


Recurrence Intervals of Warm Summer Nights



Precipitation change = streamflow change





Outcomes of Think Tank II

Identified which habitat ‘story’ to assess

Climate
Benthic
Shallow water
Open bay/Epipelagic
Salinity
Temperature
Agriculture

1)Sparks excitement
2)Feasible based on resources/data
3)Stakeholder Interest
4)Analysis is immediately useful and impactful

End-user products resulting from partnerships

Identified which habitat 'story' to assess

Analytical "story" theme	**VA**	**MD**	Total
Climate	**4**	**5**	**9**
SAV	**7**	**5**	**12**
Shallow water	8	8	16
open bay/epipelagic	5	8	13
Marsh	**6**	**4**	**10**
Temperature	7	8	15
Agriculture	8	12	20

Three "chapters" to this project

1) Complete climate analysis for near-shore Chesapeake

2) Connection to shallow water environment

3) Ecosystem Service changes resulting from wetland changes

Summary

- Temperature changes have manifested stronger than precipitation changes
- North Chesapeake had more precipitation changes than South Chesapeake
- Daily minimum temperatures have increased at a faster rate than warm temperatures
- Variability has also increased in some cases