



THE UNIVERSITY OF THE WEST INDIES
AT MONA, JAMAICA

What is happening to the Jamaican climate?



THE UNIVERSITY OF THE WEST INDIES
AT MONA, JAMAICA

Climate Change and Jamaica: Why worry?

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Part 1

RAIN A FALL, BUT DUTTY TUFF

Climate Context



1. *CLIMATE CONTEXT*

- Climatology
 - Average behaviour of weather

- Examine values of a number of climate variables
 - Temperature
 - Rainfall
 - Solar Radiation
 - Wind
 - Relative Humidity

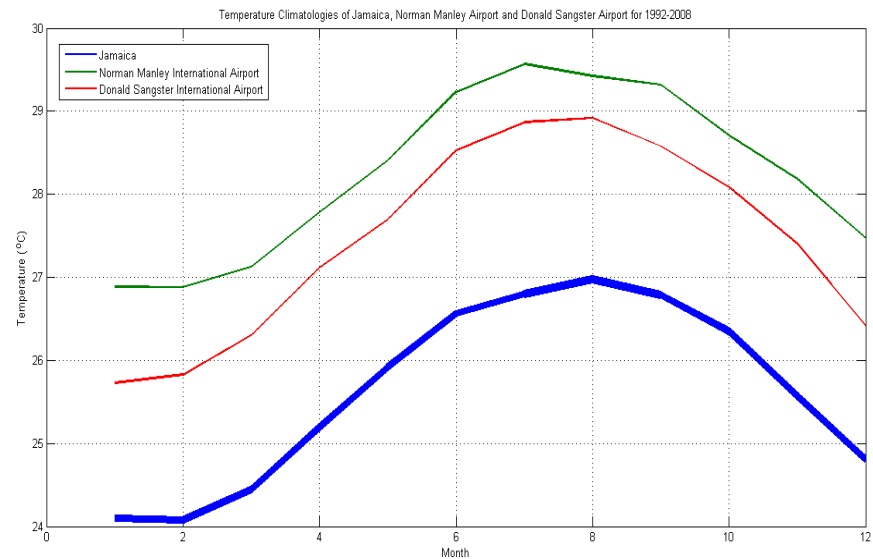


RAIN A FALL



1. CLIMATE CONTEXT

- Temperature
 - Varies with earth's orbit about the sun
- Hotter in summer (July-August)
- Range of 3°C
- Spatial variation in mean temperature across island



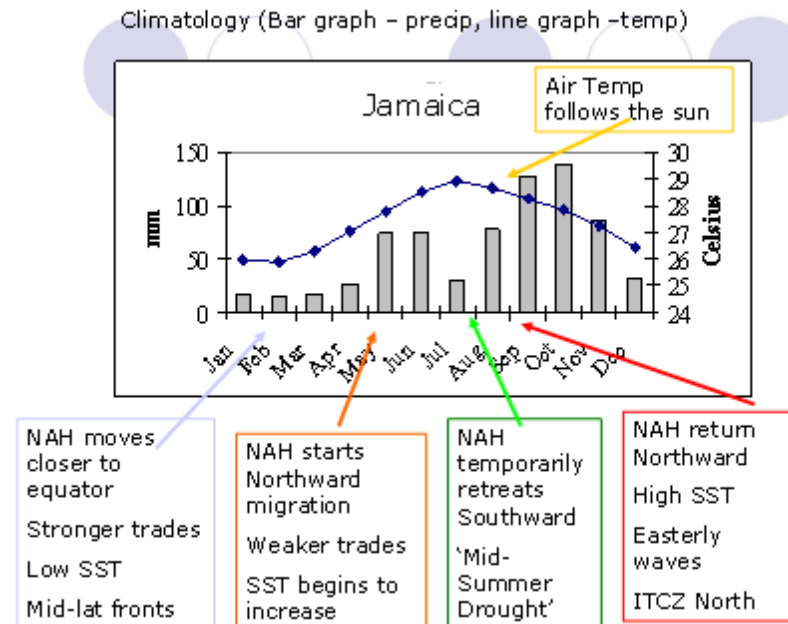
— Jamaica
— Manley
— Sangster

RAIN A FALL



1. CLIMATE CONTEXT

- Rainfall
 - Bimodal
- Early season: May-July
- Late season:
August – November
- coincides with peak hurricane season
- Mean no. of rain days:
60-200 days

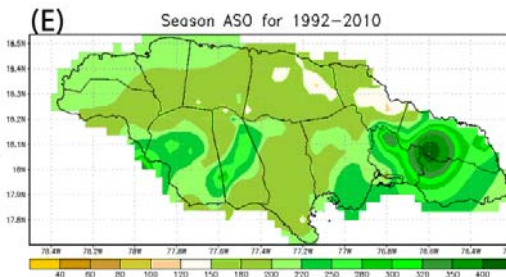
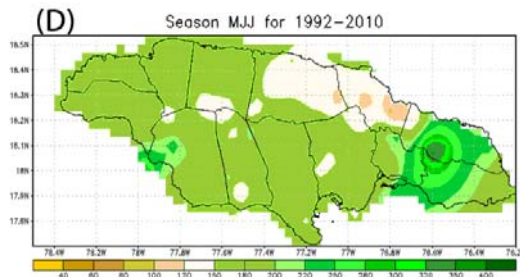
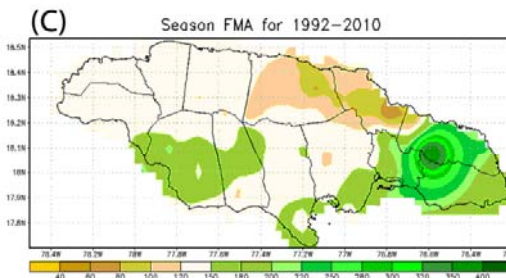
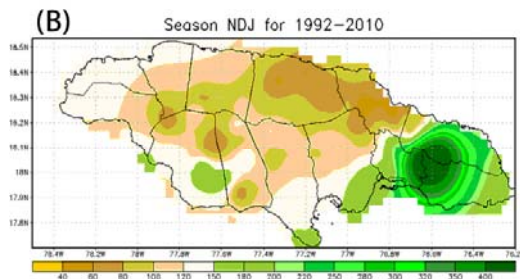
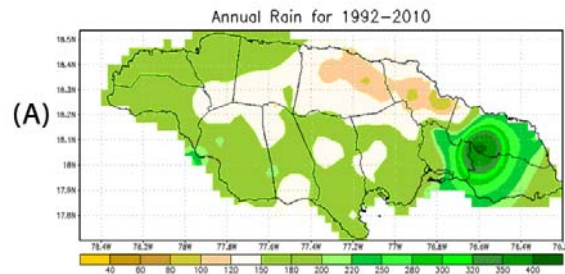


RAIN A FALL



1. CLIMATE CONTEXT

- Rainfall
- Spatial variability across the island.
- Max in Portland (Centre of max is only approximate)

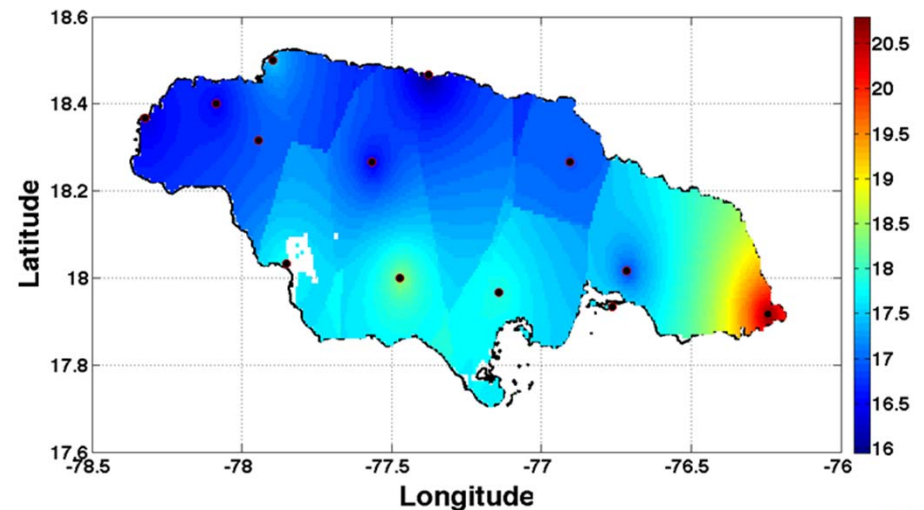


Rainfall Means



1. CLIMATE CONTEXT

- Solar
- Estimated average of 177 MJ/ m² per year of direct solar radiation.
- Very slight variation from north to south
- Indication of slightly higher values in the far eastern tip of Jamaica.

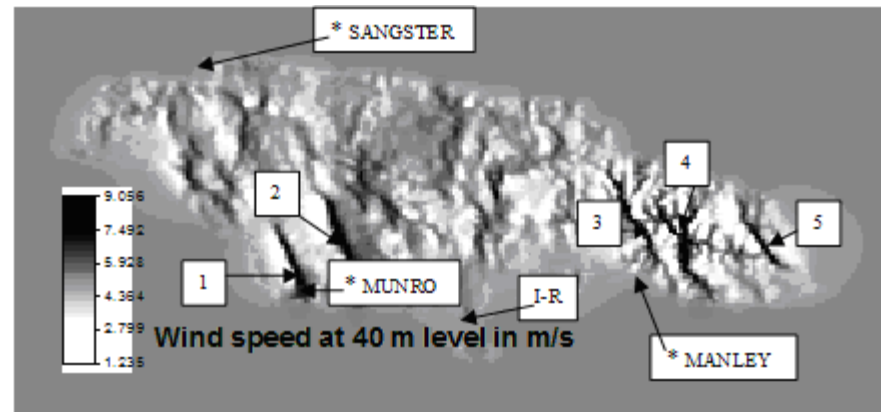


Mean global radiation across Jamaica



1. CLIMATE CONTEXT

- Wind
- Combination of prevailing winds, sea breezes and mountain and valley winds
- Prevailing winds from east or northeast is strongest influence
- Driest months = larger wind speeds
- Wettest month = smaller wind speeds



Modelled wind speed over Jamaica based on data collected at Manley and Sangster Airports and at Munro



1. CLIMATE CONTEXT

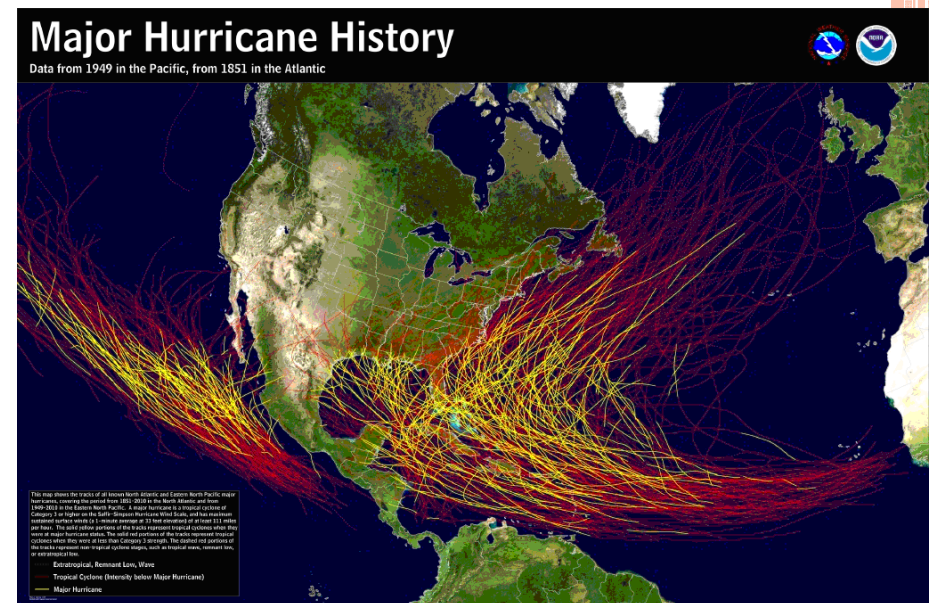
- Other Variables
- Relative humidity does not vary significantly throughout the year.
- Sunshine hours vary little throughout the year, ranging between 7 and 9 hours per day.
 - More sunlight hours in the dry season and less in the main rainy season
- Evaporation values peak approaching July

	Norman Manley International Airport			
	Relative Humidity (%)		Evaporation	Sunshine Hours (hrs)
	7am	1pm		
January	76.94	60.31	5.92	8.37
February	76.50	60.69	6.75	8.75
March	75.50	61.13	7.59	8.65
April	72.87	61.47	7.96	9.10
May	73.40	64.67	7.76	8.03
June	72.08	63.08	8.53	7.94
July	71.93	61.73	8.47	8.13
August	73.73	64.93	7.85	7.90
September	75.33	65.93	6.98	7.36
October	77.31	66.88	6.99	7.49
November	77.07	63.75	6.03	7.87
December	77.63	61.19	5.89	7.94
Annual	75.02	62.98	7.23	8.13



1. CLIMATE CONTEXT

- Hurricanes
- Easterly waves frequently mature into storms and hurricanes
- June - November



Hurricane tracks for 1851-2010



QUICK REVIEW

- Which 4 of the following are features of Jamaica's climate?



Hotter in summer



Greater wind speeds in drier months



Hurricane in April



Relative Humidity does not vary a lot



Same amount of rainfall over entire island



Early & Late rainfall seasons



QUICK REVIEW

- Which 4 of the following are features of Jamaica's climate?



Hotter in summer



Greater wind speeds in drier months



Relative Humidity does not vary a lot



Early & Late rainfall seasons



Part 2

YU NEBBA SEE SUMOKE WIDOUT FIYAH

Climate Change Observed

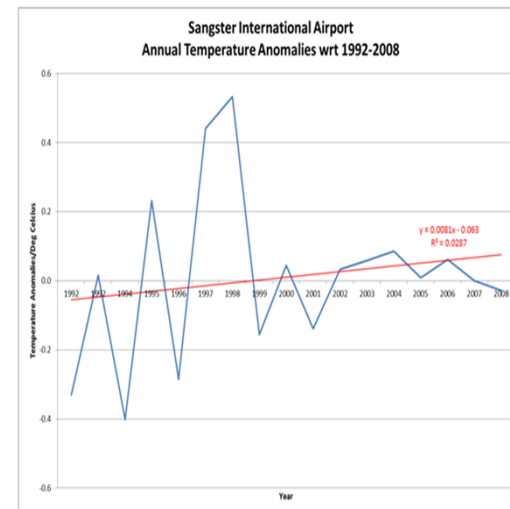
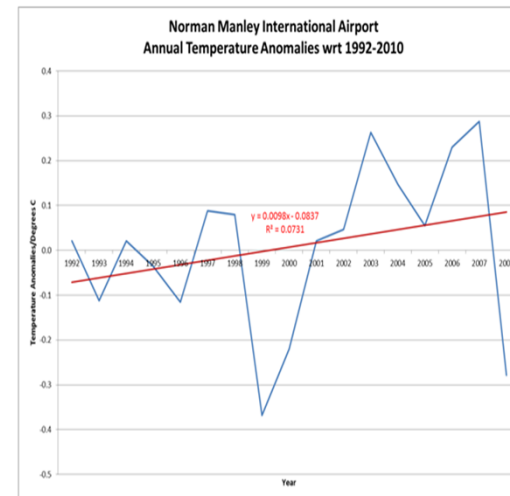


2. CLIMATE CHANGE OBSERVED

o Higher Temperatures

- Globe
- Caribbean
- Jamaica
 - o 0.1 degrees Celsius/decade for airports
 - o 0.27 degrees Celsius/decade for island

- o Percent of very warm days and very warm nights observed annually increasing



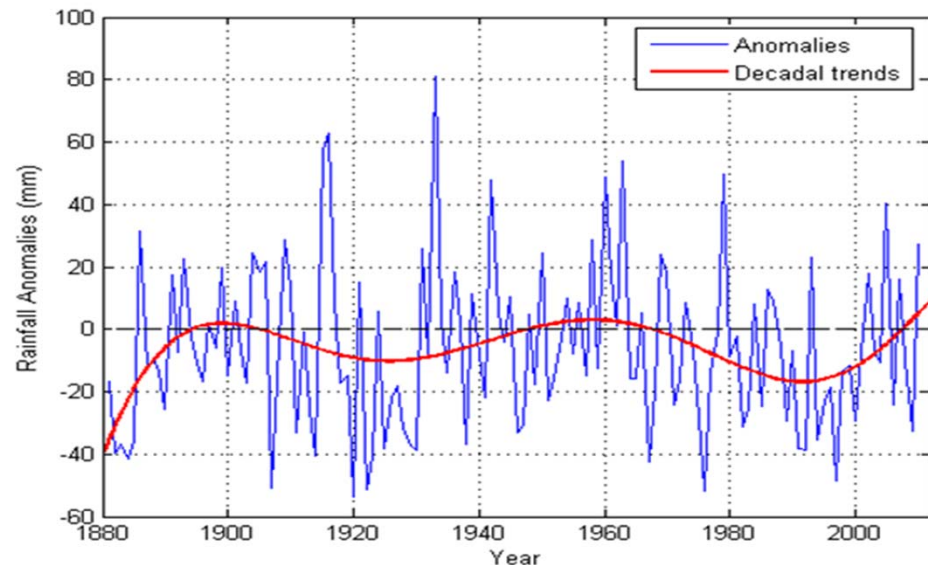
YU NEBBA SEE SUMOKE.



2. CLIMATE CHANGE OBSERVED



- Variable Rainfall
- Significant interannual (year to year) variability
- Decadal variability
 - Last decade shows rainfall trending upward:
- Mean Jamaica rainfall record shows no statistically significant trend



Jamaican rainfall (blue) with decadal trends (red)

YU NEBBA SEE SUMOKE.

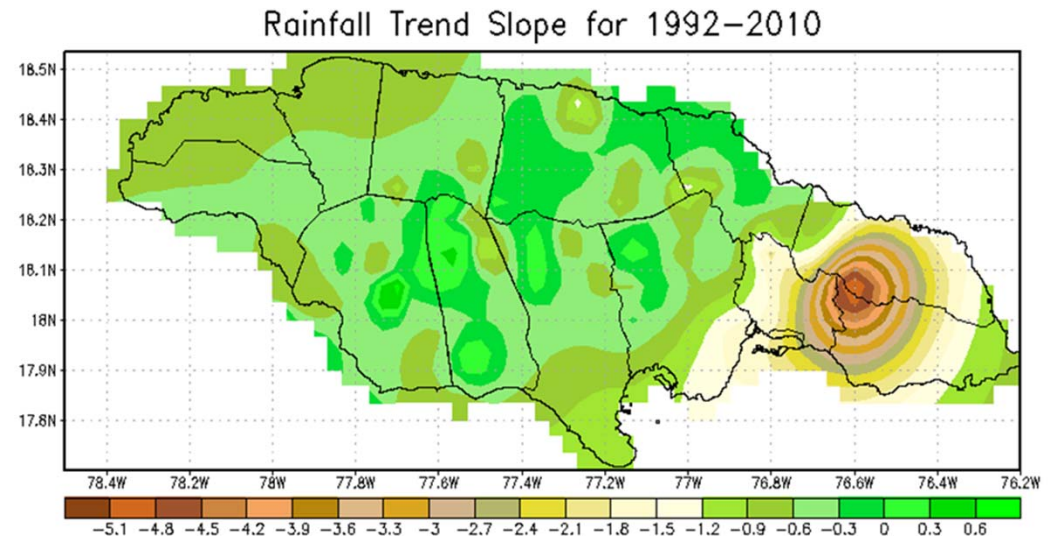


2. CLIMATE CHANGE OBSERVED



o Variable Rainfall

- o Significant decrease in the proportion of total rainfall that occurs in 'heavy' events
- o Increasing rainfall over the centre of the island and decreasing rainfall over the eastern and western parishes



Map showing Rainfall trends slope. Positive slope suggest increasing rainfall, and negative slope suggest decreasing rainfall

YU NEBBA SEE SUMOKE.

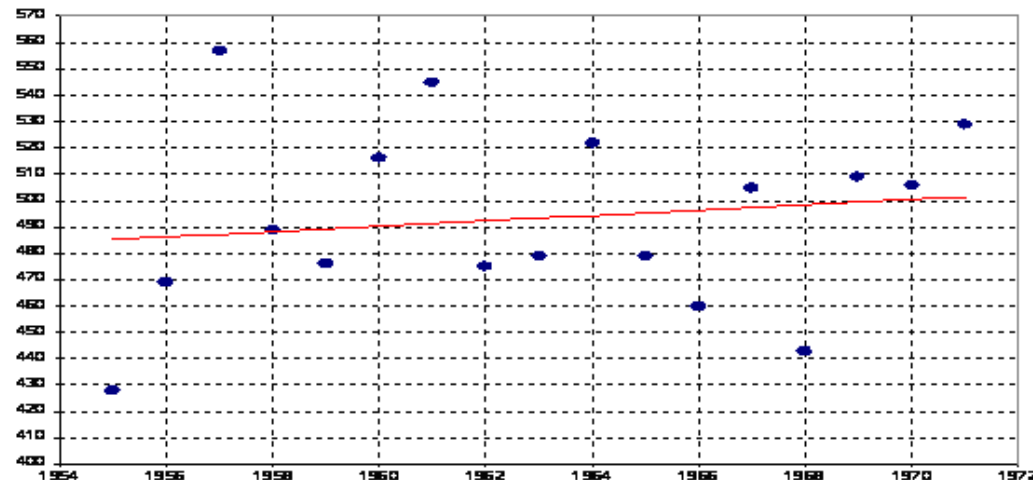


2. CLIMATE CHANGE OBSERVED



- Higher Sea Levels
- Global sea level rise over the 20th century is estimated to have been 0.17 ± 0.05 m.
- Caribbean appears to be near the global mean
- Port Royal between 1955 and 1971 also indicate a 0.9 mm/year rising trend (Horsfield, 1973).

Mean annual sea levels at Port Royal measured between 1955 and 1971.





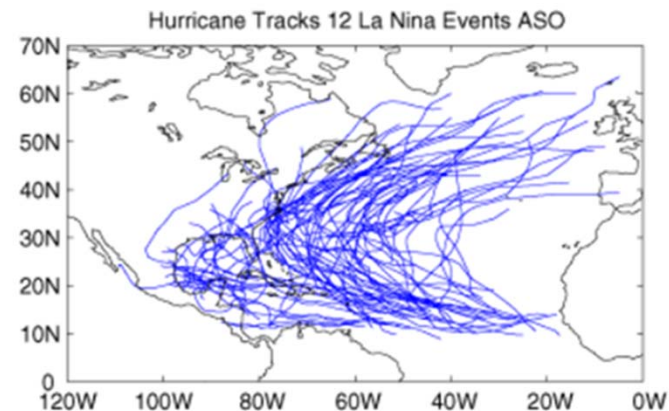
2. CLIMATE CHANGE OBSERVED

Tidal Gauge Station	Observed Trend (mm/yr)	Observation Period
Bermuda	2.04 ± 0.47	1932 – 2006
San Juan, Puerto Rico	1.65 ± 0.52	1962 – 2006
Guantanamo Bay, Cuba	1.64 ± 0.80	1973 – 1971
Miami Beach, Florida	2.39 ± 0.43	1931 – 1981
Vaca Key, Florida	2.78 ± 0.60	1971 – 2006



2. CLIMATE CHANGE OBSERVED

- **Higher Hurricane Frequency** since 1995.
- May be attributed to Atlantic multidecadal oscillation and not necessarily due to global warming (Goldenburg et al., 2001).
- Additionally El Niño and La Niña events influence the location and activity of tropical storms across the globe.





2. CLIMATE CHANGE OBSERVED

- **Other Variables**
- Significant increases in the annual and seasonal values of wind speed around Jamaica in all seasons over the period 1960-2006
- No significant trend in Relative Humidity (RH) over Jamaica

Variable	Annual	DJF	MAM	JJA	SON
Wind Speed (ms-1)	0.26	0.27	0.25	0.27	0.25
Relative Humidity (%)	0.03	0.19	-0.06	0.09	-0.11
Sunshine Hours (hrs)	0.28	0.19	0.78	0.4	-0.26
Sea surface temperatures (°C/decade)	0.04	0.01	0.02	0.07	0.07

Observed trends for 1960-2006



2. CLIMATE CHANGE OBSERVED

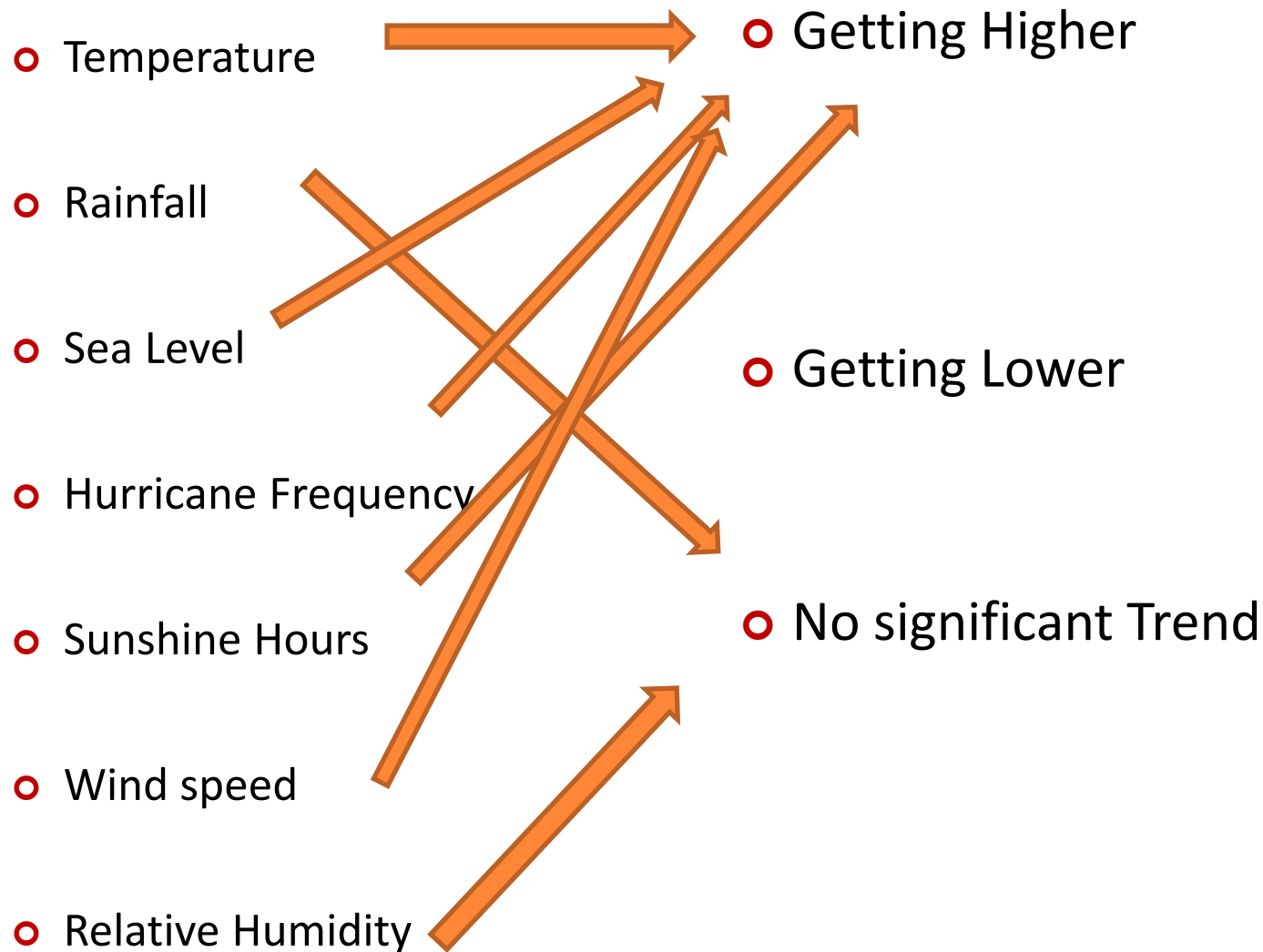
- Other Variables
- Statistically significant increases in sunshine hours in MAM and JJA for Jamaica over recent years (1983-2001).
- Statistically significant increasing trends in JJA and SON sea surface temperatures

Variable	Annual	DJF	MAM	JJA	SON
Wind Speed (ms ⁻¹)	0.26	0.27	0.25	0.27	0.25
Relative Humidity (%)	0.03	0.19	-0.06	0.09	-0.11
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Sea surface temperatures (°C/decade)	0.04	0.01	0.02	0.07	0.07



Observed trends for 1960-2006

QUICK REVIEW: CLIMATE CHANGE OBSERVED





Part 3

A NUH SAME DAY LEAF DROP
A RIVER BOTTOM IT ROTTEN

More Climate Change Expected



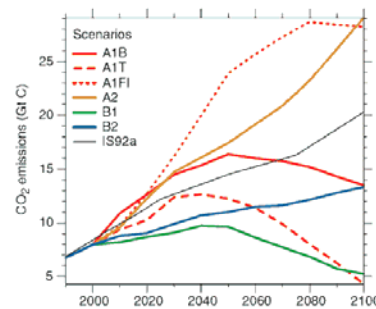
CLIMATE CHANGE EXPECTED

Reminder of how we get projections



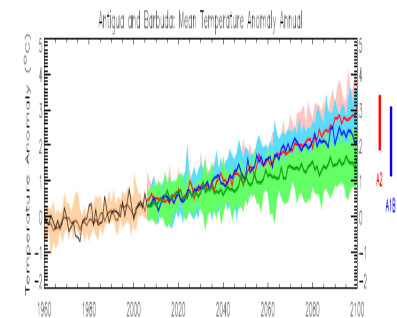
Models

GCMs or
RCMs



Scenarios

A2
A1B
B2



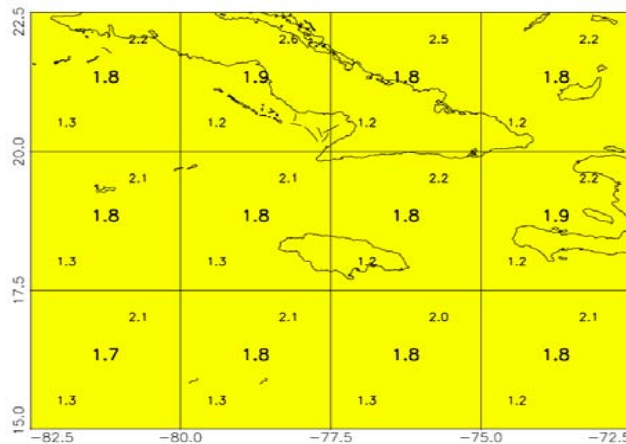
Future Climate

Temperature
Rainfall
Sea Level Rise, etc.

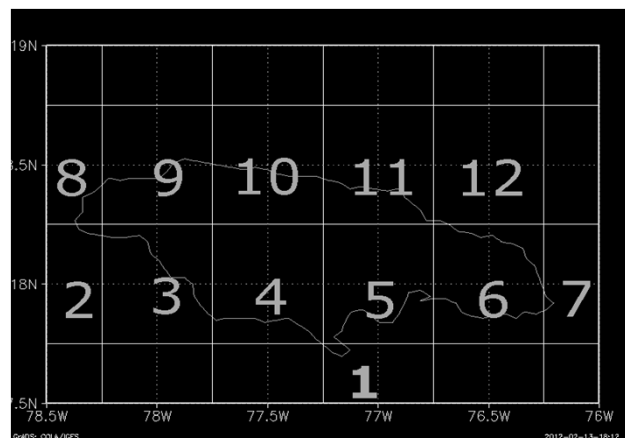


MORE CLIMATE CHANGE EXPECTED

Jamaica
on GCM
grid



Jamaica
on RCM
grid



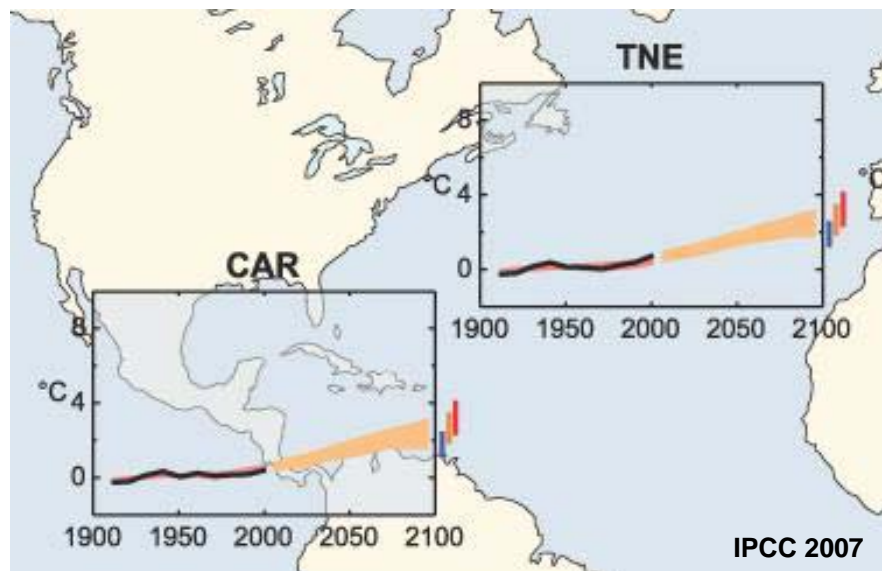
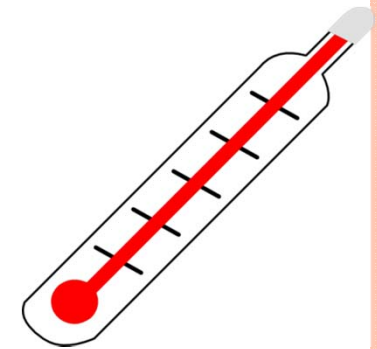
Key take home points

- **GCMS**
 - Lots of GCMs (21 ensemble) – good for range
 - GCMs have lots of climate variables
 - GCMs give one value for Jamaica
- **RCM**
 - One RCM – PRECIS but forced by 2 GCMs and 2 scenarios – still have range
 - Has 12 grid boxes for Jamaica (50 km)
 - Lots of climate variables
 - Right now end of century only



PROJECTIONS OF TEMPERATURE...

Caribbean context from GCMs



21 member ensemble

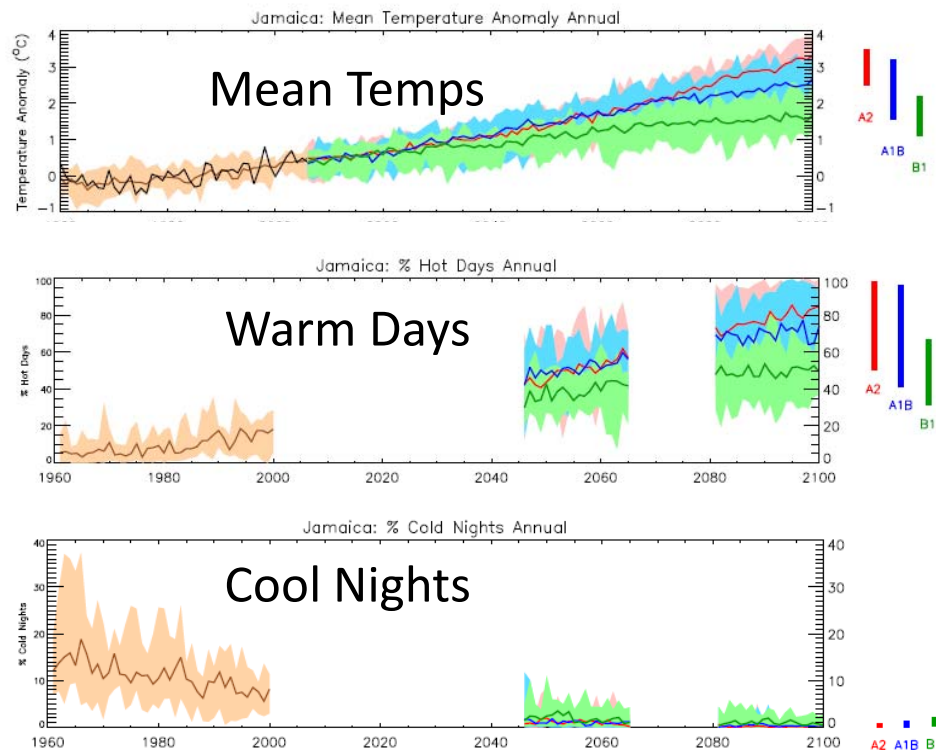
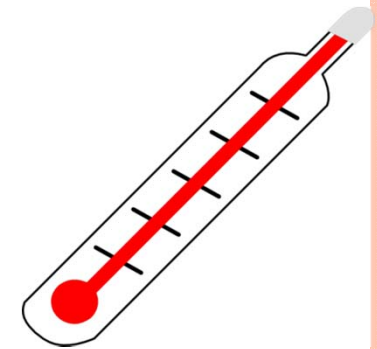
- Caribbean expected to warm 1.4 -3.2 degrees by 2100
- Greatest in SON
- 100% of days at end of century warmer than present

A NUH SAME DAY.....



PROJECTIONS OF TEMPERATURE...

Jamaica from GCMs



McSweeney et al. 2008

15 member ensemble

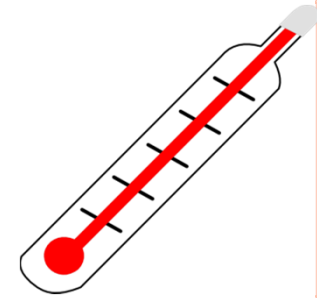
- Mean warming
 - 1.1 - 3.5 degrees by the 2090s
- Extremes
 - 30-98% of days annually will be considered 'hot' by the 2090s
- Only 2% 'cool' by the 2080s
- Most change in summer months (JJA)

A NUH SAME DAY.....



PROJECTIONS OF TEMPERATURE...

Jamaica from RCMs

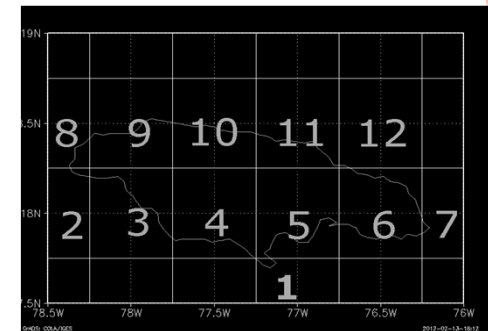


A2	GRID_1	GRID_2	GRID_3	GRID_4	GRID_5	GRID_6	GRID_7	GRID_8	GRID_9	GRID_10	GRID_11	GRID_12
JAN	2.56	2.31	4.41	4.32	3.38	3.55	2.82	2.28	3.00	2.45	2.22	2.22
FEB	2.63	2.51	3.90	3.90	4.14	4.29	3.14	2.49	2.91	2.47	2.23	2.20
MAR	2.67	2.71	3.51	3.61	4.20	4.42	3.53	2.75	2.96	2.67	2.47	2.42
APR	2.62	2.76	3.16	3.35	3.50	3.89	3.45	2.87	2.97	2.84	2.72	2.67
MAY	2.49	2.67	4.18	4.48	4.37	4.41	3.46	2.86	3.43	3.14	2.98	2.95
JUN	2.58	2.72	5.29	5.56	5.17	5.00	3.81	2.90	3.95	3.51	3.37	3.38
JUL	2.55	2.44	5.97	6.10	5.14	4.94	3.74	2.50	3.98	3.42	3.32	3.40
AUG	2.34	1.85	5.42	5.25	4.92	4.79	3.47	1.78	3.33	2.82	2.85	3.00
SEP	2.20	1.47	5.58	5.65	4.99	4.81	3.35	1.38	3.11	2.49	2.44	2.61
OCT	2.13	1.49	5.52	6.24	4.80	4.85	3.33	1.49	3.12	2.51	2.31	2.43
NOV	2.27	1.81	4.70	5.45	3.59	3.65	2.85	1.85	3.00	2.58	2.39	2.47
DEC	2.45	2.10	4.55	4.86	3.21	3.27	2.76	2.11	3.03	2.56	2.37	2.41
ANN	2.46	2.24	4.68	4.90	4.28	4.32	3.31	2.27	3.23	2.79	2.64	2.68
NDJ	2.43	2.07	4.55	4.88	3.39	3.49	2.81	2.08	3.01	2.53	2.33	2.37
FMA	2.64	2.66	3.52	3.62	3.95	4.20	3.37	2.70	2.95	2.66	2.47	2.43
MJJ	2.54	2.61	5.15	5.38	4.89	4.79	3.67	2.75	3.79	3.36	3.22	3.24
ASO	2.22	1.60	5.51	5.71	4.90	4.82	3.38	1.55	3.18	2.61	2.53	2.68

CSGM 2012

- Warming by 12 grid boxes
- Warming by month, season and annually

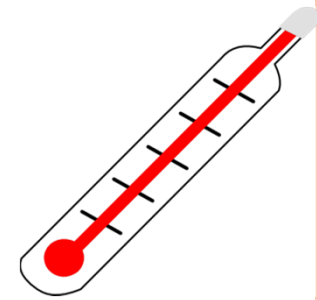
A NUH SAME DAY.....





PROJECTIONS OF TEMPERATURE...

Jamaica from RCMs

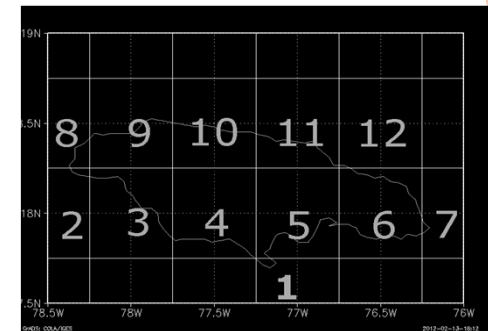


MTH	WEST		CENTRE		EAST		JAMAICA	
	A2	B2	A2	B2	A2	B2	A2	B2
JAN	3.0	2.3	3.0	2.2	3.6	2.2	3.0	2.2
FEB	3.0	2.1	3.1	2.1	4.3	2.4	3.1	2.1
MAR	3.0	2.2	3.1	2.4	4.4	3.4	3.2	2.4
APR	2.9	2.1	3.0	2.3	3.9	2.8	3.1	2.2
MAY	3.3	2.3	3.5	2.5	4.4	2.8	3.5	2.4
JUN	3.7	2.6	4.0	2.8	5.0	3.0	3.9	2.7
JUL	3.7	2.8	4.1	3.0	4.9	3.0	4.0	2.9
AUG	3.1	2.7	3.6	2.8	4.8	2.9	3.5	2.7
SEP	2.9	2.6	3.6	2.8	4.8	3.0	3.3	2.7
OCT	2.9	2.5	3.6	2.7	4.8	2.7	3.4	2.6
NOV	2.8	2.4	3.3	2.5	3.7	2.3	3.1	2.4
DEC	2.9	2.4	3.1	2.4	3.3	2.3	3.0	2.3

CSGM 2012

- Warming by west (grid boxes 2,3 8, 9); centre (1,4,5,10, 11); east (6)
- Warming by month, season and annually

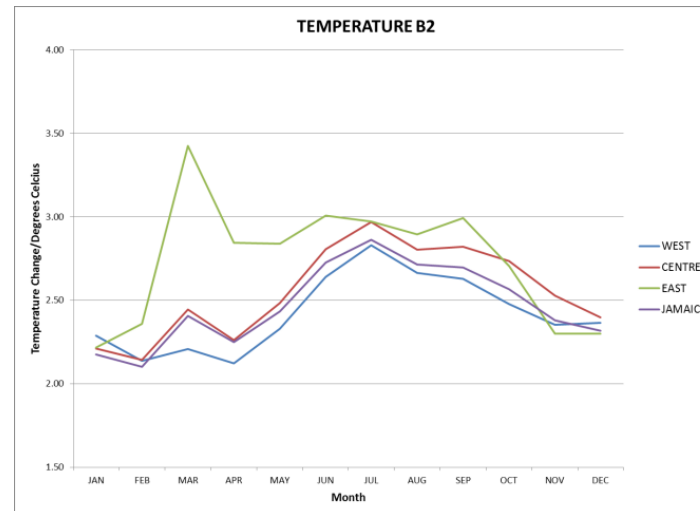
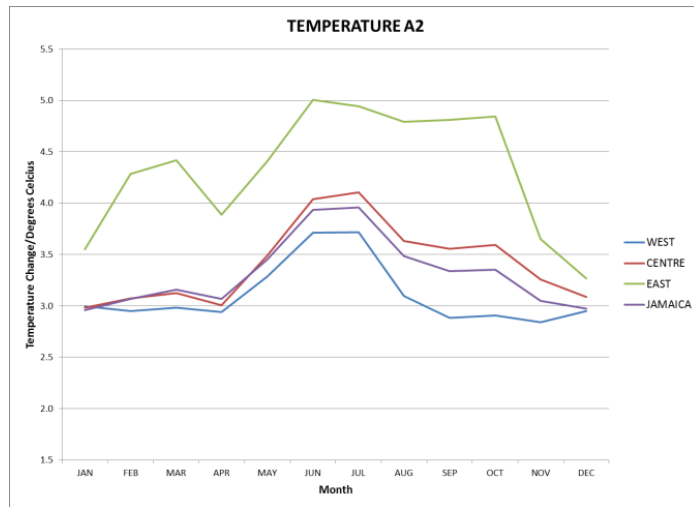
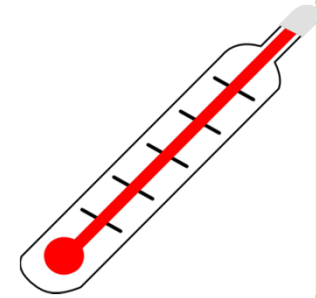
A NUH SAME DAY.....





PROJECTIONS OF TEMPERATURE...

Jamaica from RCMs



CSGM 2012

- Figure 7.2.1**
- Warming expected across the island 2.9°C and 3.4°C by the 2080s
 - Greatest warming in JJA (up to 5 degrees warmer than present)
 - Some areas may warm faster than others e.g. south and east



QUICK REVIEW

- What do we expect to happen to temperatures over Jamaica towards the end of the century?
 1. Increase
 2. Decrease
 3. No change
 4. Still unsure (No consensus)



QUICK REVIEW

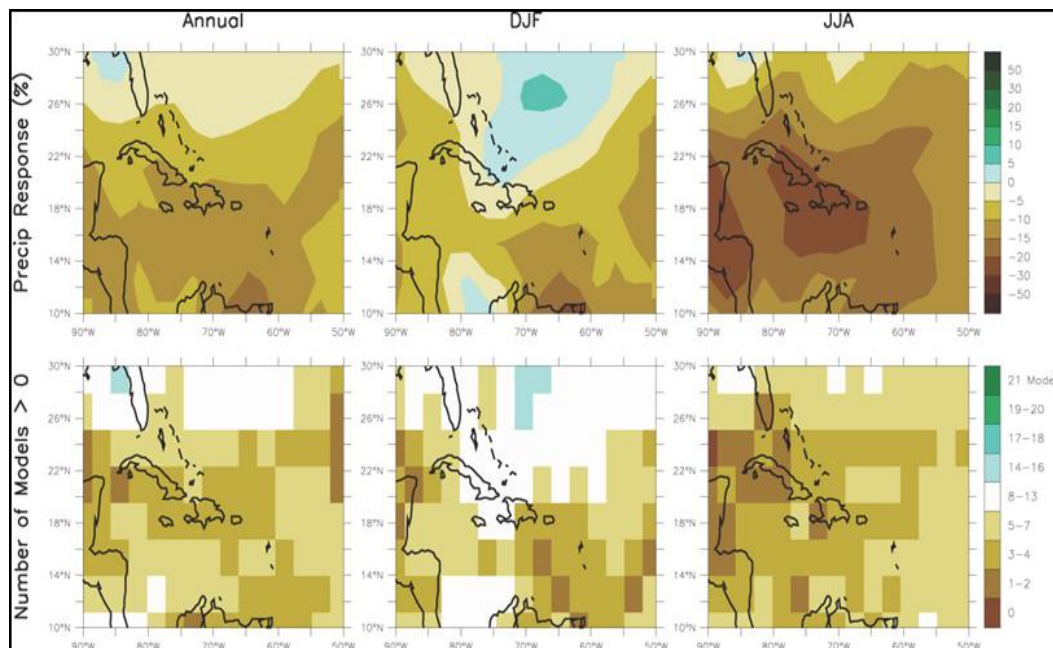
- What do we expect to happen to temperatures over Jamaica towards the end of the century?

1. Increase



PROJECTIONS OF RAINFALL...

Caribbean context from GCMs



IPCC 2007

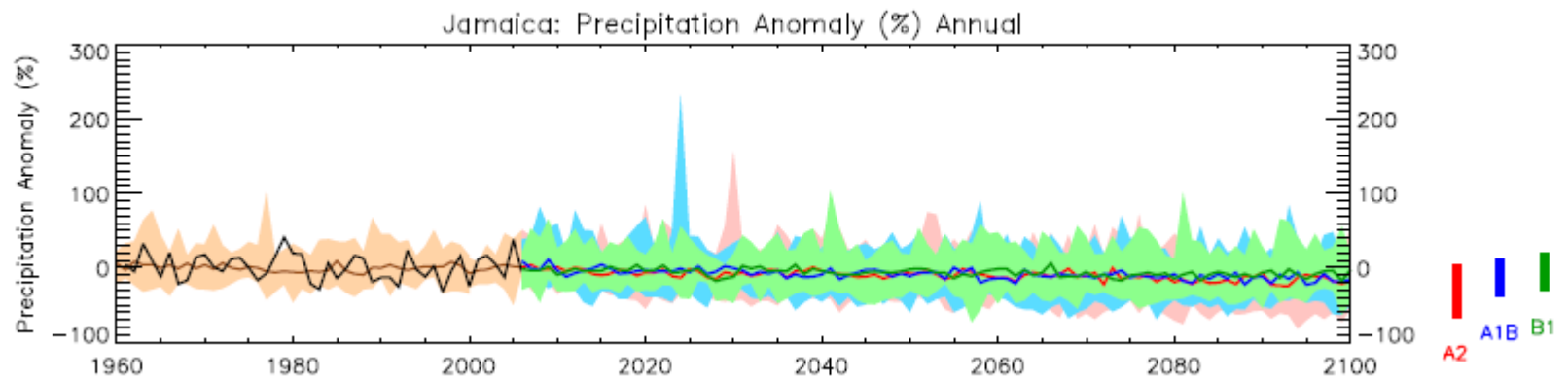
21 member ensemble

- Drying across the Caribbean Basin
 - Most models agree
 - -39% to +11% by end of century
- Minimal interannual variability



PROJECTIONS OF RAINFALL...

Jamaica from GCMs



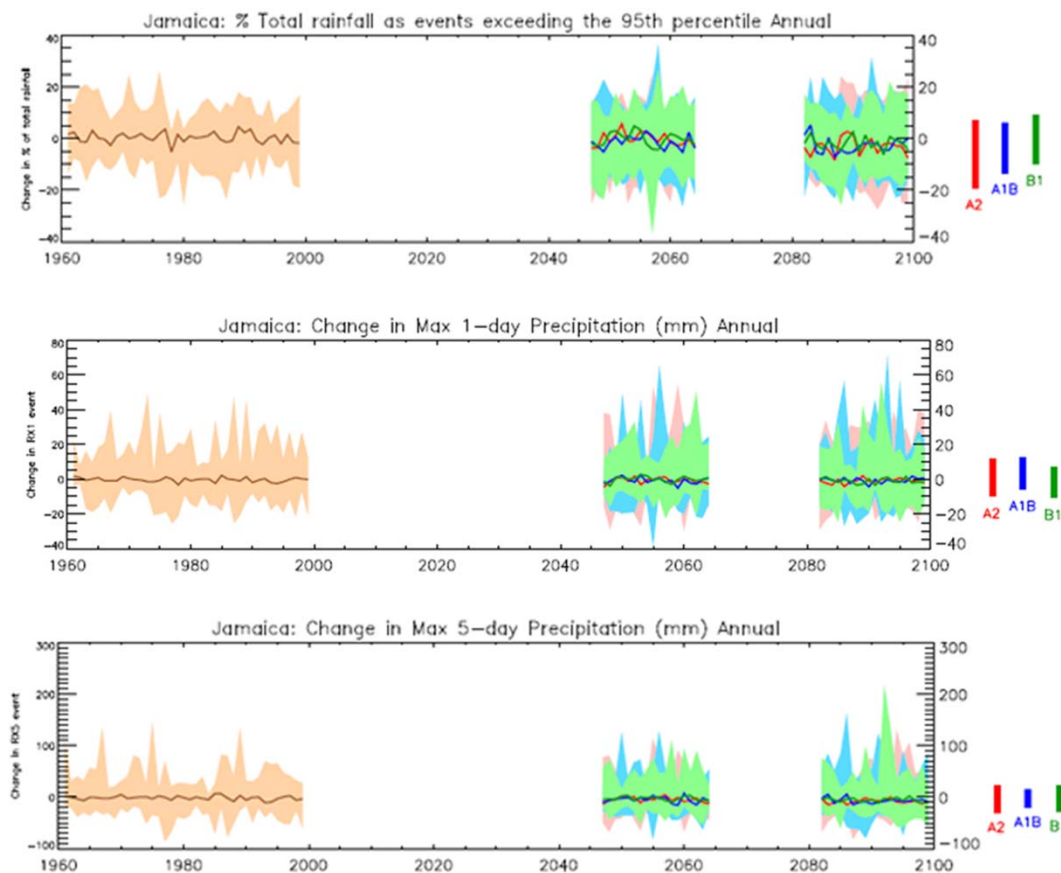
McSweeney et al. 2008

- -44% to +18% by the 2050s and -55% to +18% by the 2080s
- Drier JJA (early wet season) and SON (late wet season)



PROJECTIONS OF RAINFALL...

Jamaica from GCMs



McSweeney et al. 2008

15 member ensemble

Rainfall extremes:

- Mixed across the ensemble.
- Tendency for decreases in rainfall extremes.



PROJECTIONS OF RAINFALL...

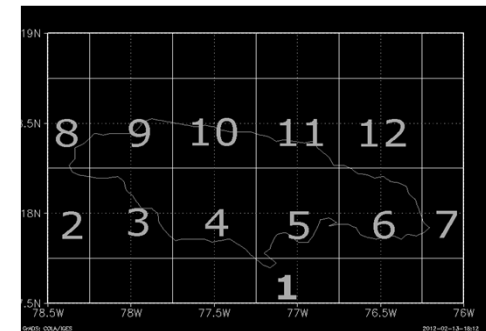


Jamaica from RCMs

A2	GRID_1	GRID_2	GRID_3	GRID_4	GRID_5	GRID_6	GRID_7	GRID_8	GRID_9	GRID_10	GRID_11	GRID_12
JAN	-30.9	-42.0	-50.9	-54.5	-38.3	-37.3	-23.5	-45.6	-43.3	-60.1	-51.8	-48.7
FEB	-13.6	20.5	-6.7	-19.1	-17.3	-25.9	-22.0	-15.3	5.4	-42.6	-43.2	-38.6
MAR	19.7	46.8	29.0	19.3	6.5	-13.7	-10.7	14.3	9.9	-21.5	-36.1	-30.3
APR	7.9	62.6	37.6	22.3	9.0	-5.9	-8.3	37.0	67.3	-3.0	-5.2	-6.7
MAY	-63.7	-61.4	-51.4	-58.0	-50.7	-48.0	-41.4	-59.3	-39.3	-71.4	-71.8	-58.0
JUN	-78.4	-77.8	-74.6	-78.3	-65.9	-59.2	-53.9	-76.0	-51.6	-71.6	-57.5	-60.9
JUL	-70.2	-73.5	-72.3	-74.8	-57.5	-52.7	-49.8	-84.0	-53.6	-65.5	-23.3	-30.7
AUG	-73.1	-67.2	-64.9	-65.9	-52.6	-42.4	-39.3	-84.1	-61.5	-60.8	10.0	-10.1
SEP	-75.6	-73.0	-72.8	-79.3	-62.1	-47.9	-42.5	-88.0	-76.2	-75.4	-34.0	-41.1
OCT	-74.5	-78.4	-66.8	-78.7	-68.5	-66.0	-58.9	-84.1	-76.4	-82.5	-77.7	-77.1
NOV	-52.2	-61.3	-42.0	-55.9	-41.3	-51.8	-44.5	-62.6	-58.4	-77.1	-77.7	-69.1
DEC	-73.1	-77.6	-66.5	-71.2	-54.6	-56.2	-45.5	-69.1	-70.0	-78.9	-78.6	-66.5
ANN	-63.2	-62.9	-57.9	-64.4	-51.5	-48.6	-42.1	-66.3	-51.9	-67.0	-63.9	-54.2
NDJ	-58.2	-65.5	-50.7	-60.6	-45.3	-51.3	-41.7	-63.0	-60.8	-75.7	-75.2	-64.8
FMA	5.8	45.5	25.2	11.1	1.4	-13.4	-12.6	12.2	28.6	-23.7	-30.5	-25.4
MJJ	-70.3	-69.0	-66.1	-70.1	-58.0	-53.3	-48.3	-70.6	-46.8	-70.3	-65.2	-53.9
ASO	-74.5	-75.3	-68.2	-76.0	-62.4	-53.2	-47.6	-85.2	-73.1	-77.2	-63.1	-58.9

CSGM 2012

- % changes by 12 grid boxes
- % changes by month, season and annually



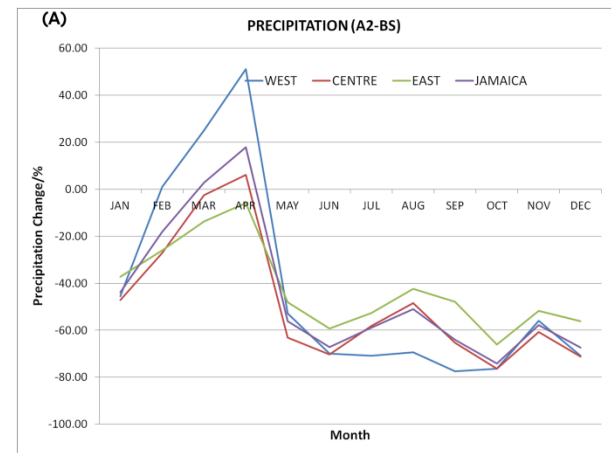


PROJECTIONS OF RAINFALL...



Chapter 7: Jamaica from RCMs

MTH	WEST		CENTRE		EAST		JAMAICA	
	A2	B2	A2	B2	A2	B2	A2	B2
JAN	-45.4	-25.0	-47.1	-17.8	-37.3	-8.3	-43.9	-18.6
FEB	1.0	4.6	-27.2	-13.2	-25.9	-9.5	-18.2	-6.5
MAR	25.0	-21.8	-2.4	-37.2	-13.7	-35.3	2.8	-32.3
APR	51.1	30.6	6.2	8.7	-5.9	-0.2	17.9	14.1
MAY	-52.8	-14.8	-63.1	-12.5	-48.0	-9.7	-56.2	-11.8
JUN	-70.0	-42.8	-70.3	-37.0	-59.2	-25.4	-67.1	-35.1
JUL	-70.8	-55.0	-58.3	-40.0	-52.7	-23.1	-59.0	-38.7
AUG	-69.4	-56.3	-48.5	-36.3	-42.4	-14.7	-51.0	-35.9
SEP	-77.5	-61.8	-65.3	-46.7	-47.9	-26.6	-64.0	-45.8
OCT	-76.4	-51.3	-76.4	-60.0	-66.0	-42.5	-74.1	-54.0
NOV	-56.1	-25.0	-60.8	-43.7	-51.8	-34.5	-57.8	-36.0
DEC	-70.8	-45.8	-71.3	-53.3	-56.2	-40.5	-67.3	-47.8



CSGM 2012

- May onward projected to get drier, irrespective of scenario or area
 - Models agree that JJA will get drier by end of century
 - East- throughout the year
- Toggle between west and east in dry months and wet months



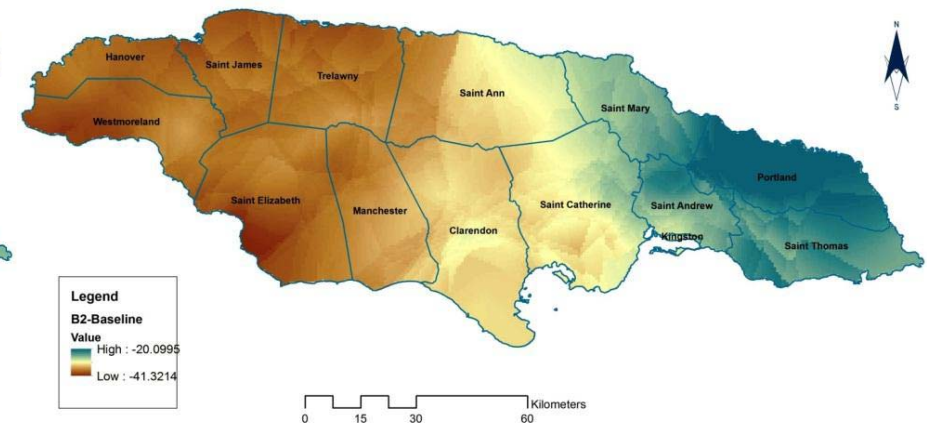
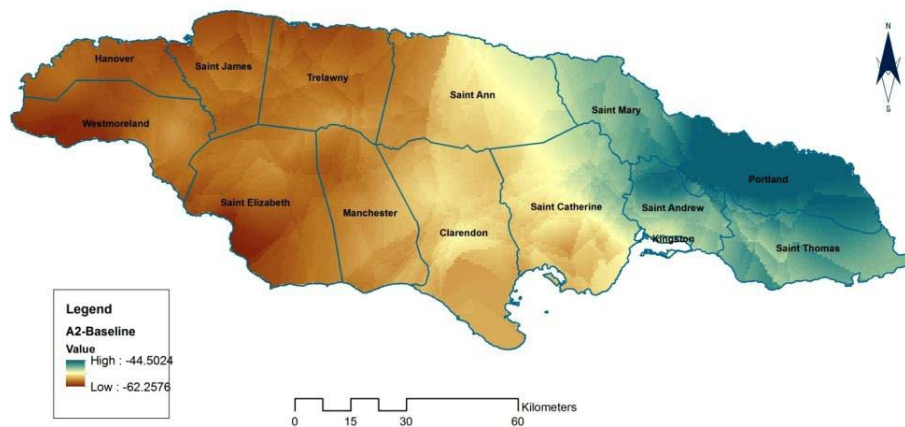
PROJECTIONS OF RAINFALL...



Jamaica from RCMs

A2

B2



CSGM 2012

- Most severe in the west and least severe in Portland in annual



QUICK REVIEW

- What do we expect to happen to **summer rainfall** over Jamaica towards the end of the century?
 1. **Increase**
 2. **Decrease**
 3. **No change**
 4. **Still unsure (No consensus)**



QUICK REVIEW

- What do we expect to happen to **summer rainfall** over Jamaica towards the end of the century?

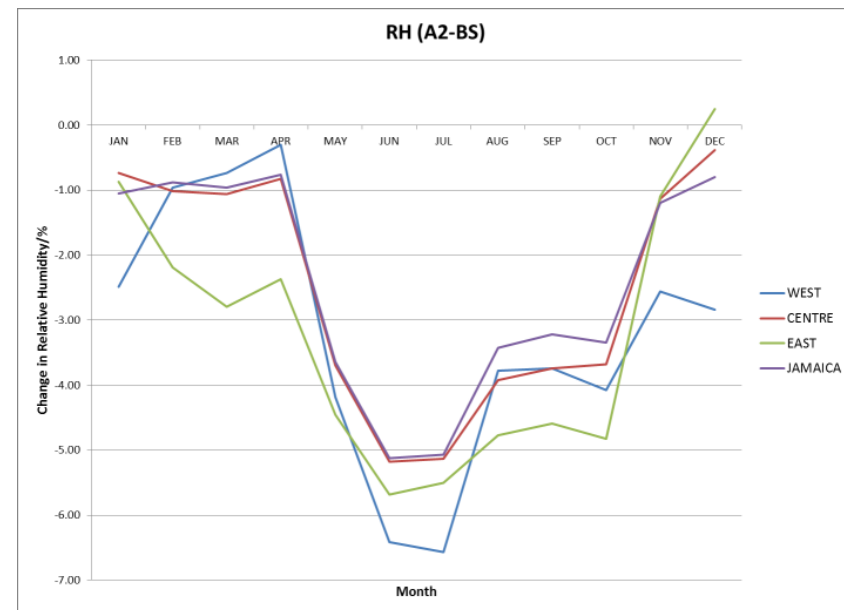
2. Decrease



PROJECTIONS OF OTHER VARIABLES...

Relative Humidity for Jamaica from RGCMs & RCMs

- May not be representative of Jamaica in GCMs
 - Small increases- DJF, MAM
- RCMs
 - General decrease throughout the year-greatest in JJA
 - -1.1 to -1.7% by the 2080s under A2



CSGM 2012



PROJECTIONS OF OTHER VARIABLES...

Wind speeds for Jamaica from RGCMs & RCMs

- GCMs
 - No consensus
 - May increase

- RCMs
 - Decreases in wind speed by 2080s under A2
 - Greatest in SON by -0.3 to -0.5 ms^{-1}



PROJECTIONS OF OTHER VARIABLES...

Sunshine hours and sea surface temperatures for Jamaica from RGCMs & RCMs

○ GCMs

- Most models suggest increase in sunshine hours under A2
 - -0.2 to +0.9 hours per day
 - Greatest in JJA
- Higher sea surface temperatures (SSTs)
 - +0.9°C and +2.7°C by the 2080s
 - Greatest in SON

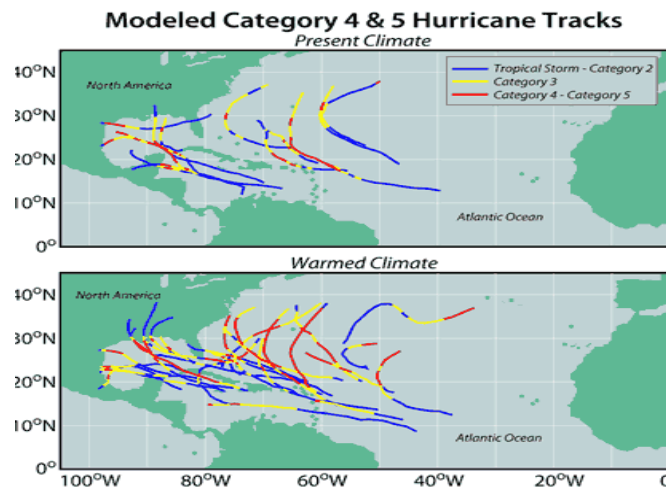
○ RCMs

- Changes in sunshine hours surpass GCM projections
 - Increase by +1.4 hours per day by 2080s under A2
- No SST projections from RCMs

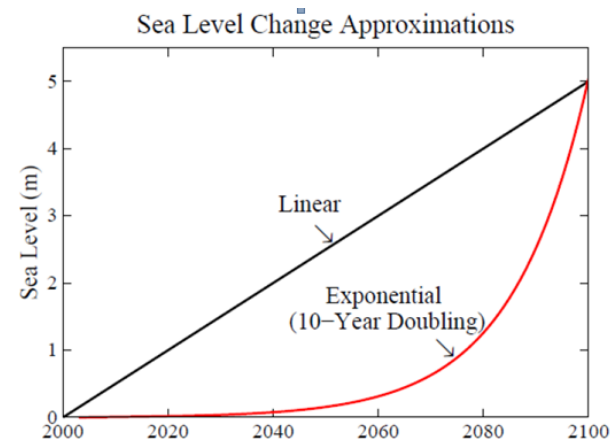


PROJECTIONS OF OTHER VARIABLES...

Hurricanes and Sea Level Rise from GCMs



Bender et al., 2010



After Hansen, 2007

CARIBSAVE Climate Change Risk Atlas – Jamaica (2011)

- Difficult to project for the region
- Increase in rainfall intensity associated with tropical storms
- Storm surges could intensify if hurricanes become more intense and sea levels rise
- 0.18-0.59m by 2100 relative to 1980s to 1990s



QUICK REVIEW

- Which of the following variables are expected to increase towards the end of the century?
 1. **Sunshine Hours**
 2. **Relative Humidity**
 3. **Sea Level Rise**
 4. **Rainfall intensity associated with tropical storms**
 5. **Sea Surface Temperatures**
 6. **Wind speeds**



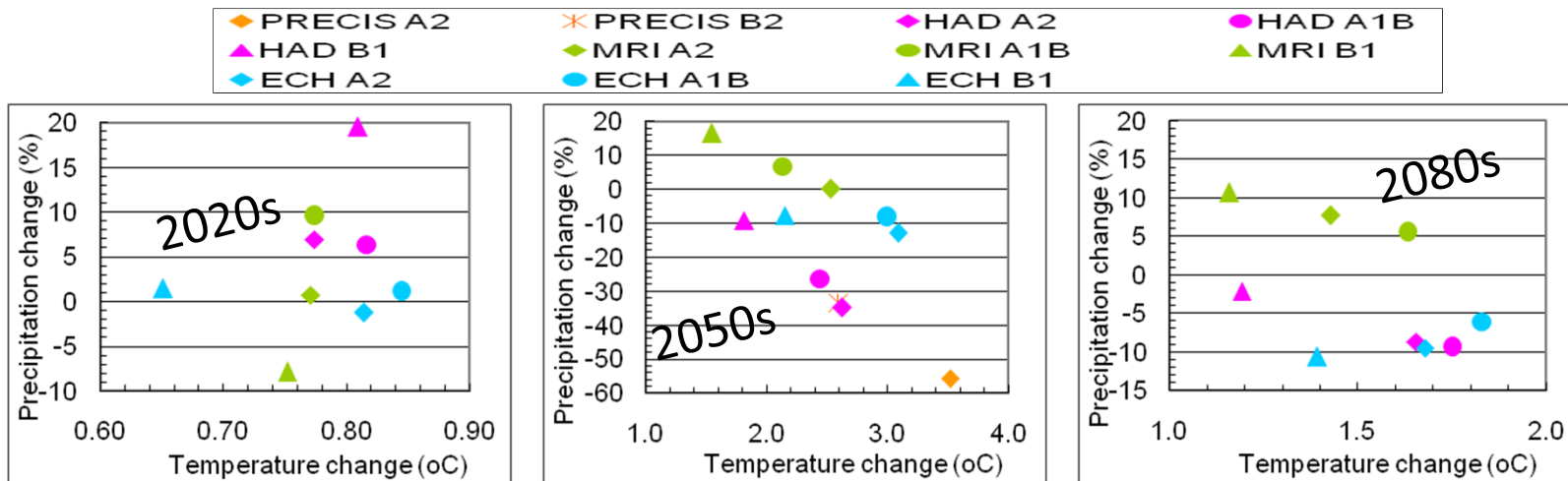
QUICK REVIEW

- Which of the following variables are expected to increase towards the end of the century?
 1. **Sunshine Hours**
 2. **Sea Level Rise**
 3. **Sea Level Rise**
 4. **Rainfall intensity associated with tropical storms**
 5. **Sea Surface Temperatures**



PROJECTIONS...

Jamaica from GCMs and RCMs



		2020s		2050s		2080s	
Annual	T (°C)	+0.65	+0.85	+1.16	+1.83	+1.55	+3.52
	Pcp (%)	-7.85	+19.51	-10.61	+10.70	-55.60	+16.49
NDJ	T (°C)	+0.58	+0.93	+0.96	+1.82	1.42	3.15
	Pcp (%)	-3.07	+18.43	-11.68	+22.58	-55.09	+16.97
FMA	T (°C)	+0.62	+0.88	+1.12	+1.76	+1.47	+3.18
	Pcp (%)	-15.20	+48.19	-13.22	+19.53	-22.87	+24.00
MJJ	T (°C)	+0.57	+1.03	+1.16	+1.85	+1.73	+4.00
	Pcp (%)	-32.24	+23.62	-29.9	-2.09	-60.43	-1.18
ASO	T (°C)	+0.73	+0.93	+1.16	+1.96	+1.58	+3.70
	Pcp (%)	-9.8	+37.92	-16.63	+32.92	-66.79	+33.42



THE TAYLOR TRUTH (SUMMARIZED)

Jamaica's climate has changed.

Jamaica's climate will continue to change.

Jamaica's climate demands change