Towards Improvement of Climate Change Projections and Environmental Monitoring in the Caribbean Region

Christopher L. Castro
Department of Atmospheric Sciences
University of Arizona
Tucson, Arizona, USA

Pan American Institute for Geography and History
Geophysics Commission Chair, U.S. National Section

Invited Public Lecture
University of the West Indies
Kingston, Jamaica
October 12, 2010

Presentation Outline

Brief personal background

Overview of some major IPCC conclusions

Specific climate change concerns of greatest relevance for the Caribbean and their physical causes

Can use of a regional atmospheric model improve climate change projections

Improvement of real-time environmental monitoring.

Acknowledgements: S. Raucher, D. Enfield, A. Douglas, C. Wang, J. Braun for assistance in gathering information for this presentation. U.S. Department of State sponsored this visit and thanks to U.S. Embassy staff in Kingston.

Professional Background

Assistant Professor, Department of Atmospheric Sciences, University of Arizona, Tucson

Recently appointed to chair Geophysics Commission, U.S. National Section of Pan American Institute for Geography and History (PAIGH)

M.S. and Ph.D. degrees from Colorado State University, Department of Atmospheric Science

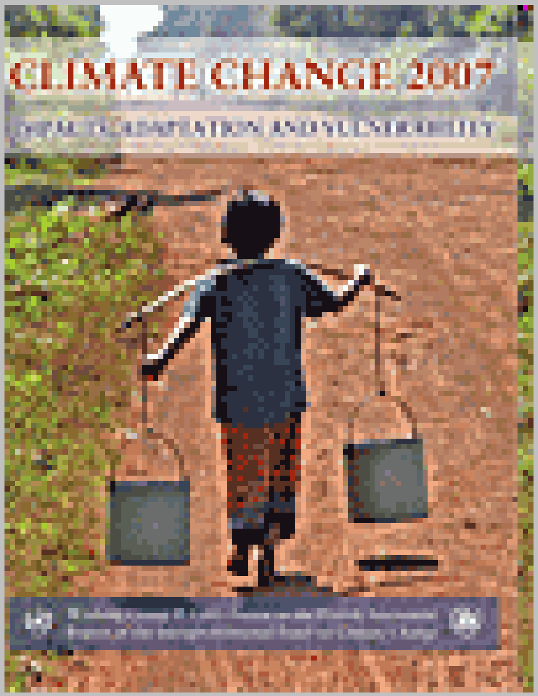
B.S. in Meteorology, Penn State

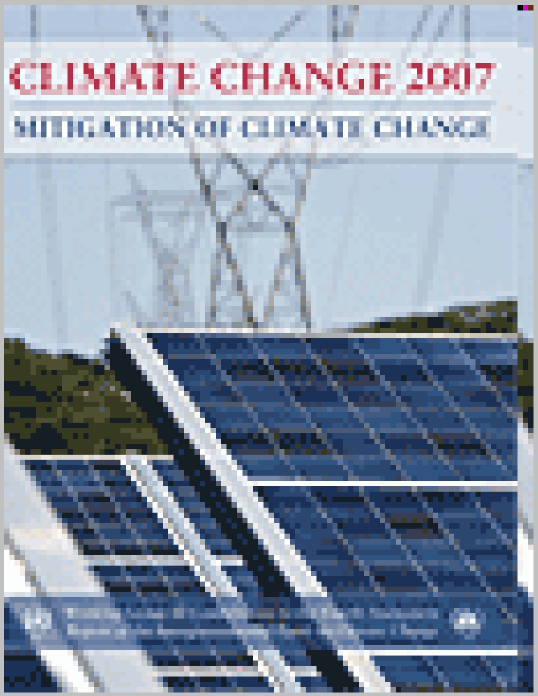
Research areas include: Climate variability and change, land-atmosphere interactions, regional atmospheric models, and the North American Monsoon

I trace my roots back to this part of the world, so it has a special significance for me…

JUNCOS, PUERTO RICO
Grandparent's birthplace and where they're buried

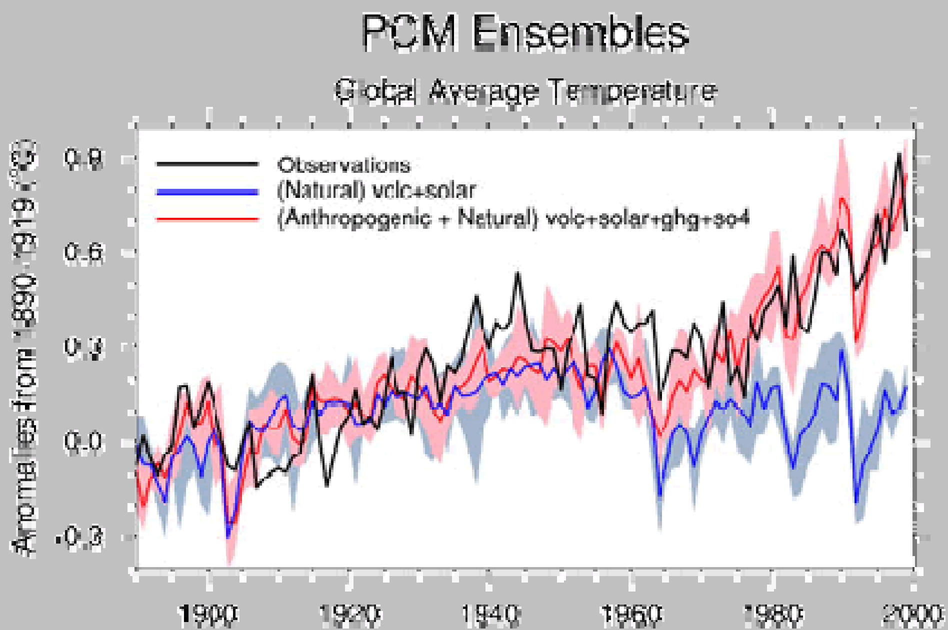
Intergovernmental Panel on Climate Change (Still) the best available assessment that reflects scientific consensus





In spite of scientific consensus, the reality of climate change in the United States is still a controversial matter politically. This presentation does not reflect any official position of the United States government on this issue.

Message from GCM attribution studies: Climate change is happening NOW



Anthropogenic climate change signal starts to become apparent after about 1980.

Find lots of abrupt transitions in a wide variety of climate-related data that occur about this time.

Suggests a philosophical question to think about later: Do we need to shift the paradigm from how to improve climate projections to how to improve monitoring for better real time hazard mitigation?

Global and Continental Temperature Change

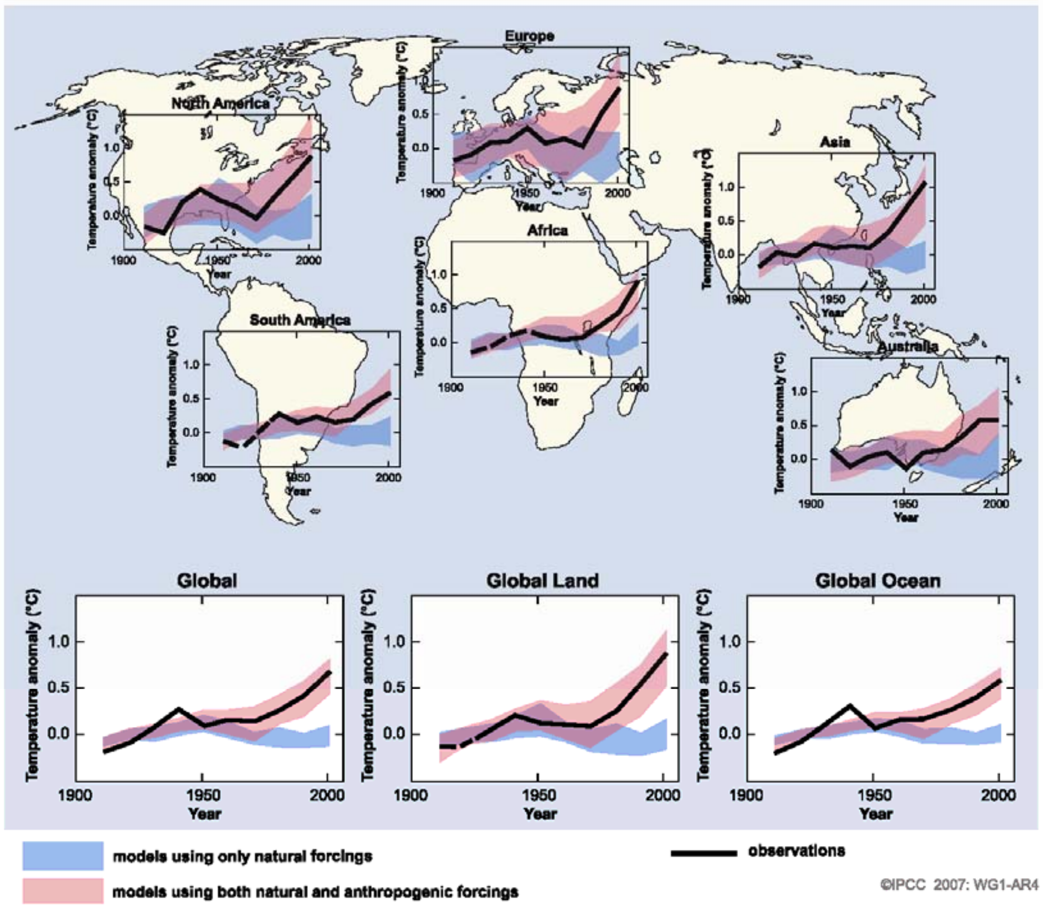
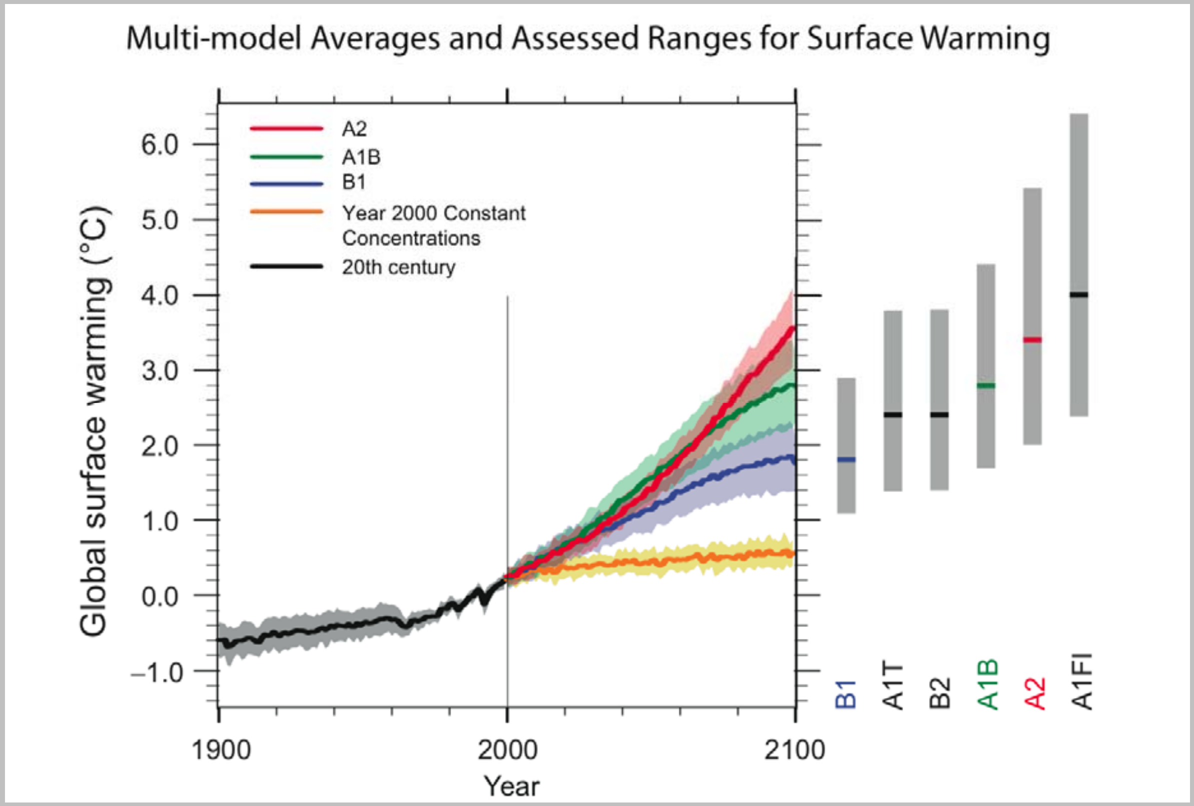


Figure SPM.4. *Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from five climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. {FAQ 9.2, Figure 1}*

IPCC Model Scenarios for future global mean temperature



PROJECTED GLOBAL MEAN TEMPERATURE INCREASE OF ABOUT 1.5 - 4°C FROM TODAY.

We are committed to more warming NO MATTER WHAT WE DO.

"Business as usual" IPCC scenario (A2) is probably the most preferable one for climate change projection.

Big picture, condensed message on IPCC-projected precipitation changes…

Whatever the current climate is gets more extreme.

Wet regions and seasons generally get wetter

Dry regions and seasons generally get drier and hotter.

Projected Patterns of Precipitation Changes

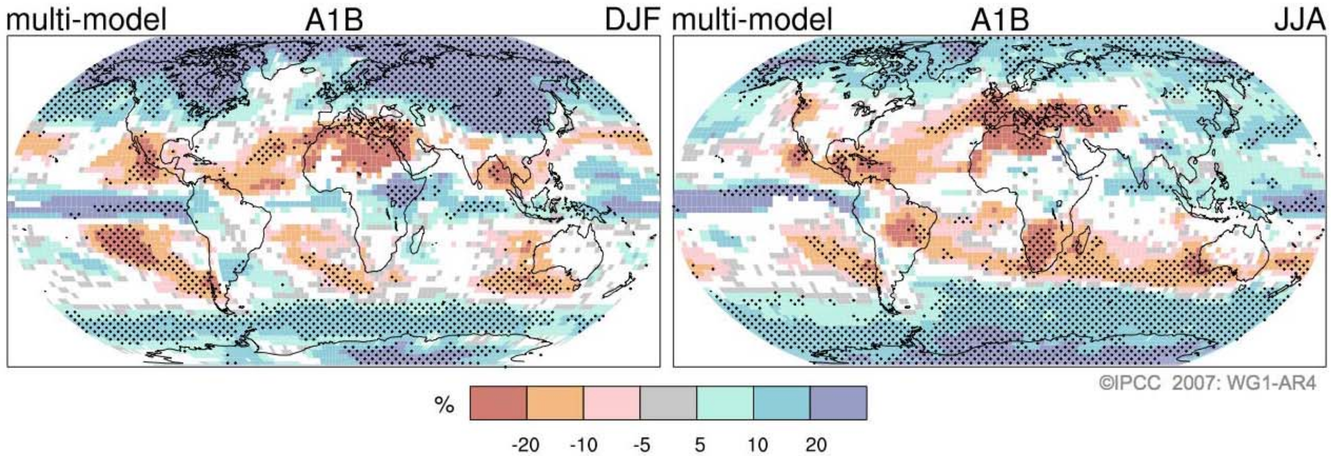


FIGURE SPM-7. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}

Subtropical zones, including Caribbean, are projected to become drier.
Most severe drying centered on the rainy season (JJA).

Reflects coherent changes in the general circulation:

- **Poleward retreat and weakening of mid-latitude jet stream**
- **Expansion of subtropical highs**
- **More intense rainfall in intertropical convergence zone**

Wildcard: How do tropical cyclones change in frequency and intensity?

Climate change questions for Caribbean Region

1. **Should we believe that global climate models have an adequate enough treatment of physical mechanisms of convective rainfall in the tropics and subtropics?**

2. **Are climate change projections consistent with what is already happening, if we accept that the global climate of our planet has been significantly altered by human beings for the last thirty years?**

3. **What can be done to improve climate change projections? Do we already have enough information to take societal action to confront climate change?**

4. **What is the most effective response that Caribbean nations can take, given limited economic resources: drastically altering their economies to reduce greenhouse gases and/or better environmental monitoring and mitigation?**

Effects most relevant for Caribbean region

Rainfall intensity

Drought Severity

Tropical cyclone intensity

Sea-level rise

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems [4.4, 5.4]	Water resources [3.4]	Human health [8.2, 8.4]	Industry, settlement and society [7.4]
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	Virtually certain[b]	Increased yields in colder environments; decreased yields in warmer environ-ments; increased insect outbreaks	Effects on water resources relying on snow melt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	Very likely	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g., algal blooms	Increased risk of heat-related mortality, espec-ially for the elderly, chronically sick, very young and socially-isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	Very likely	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	Likely	Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortages for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Intense tropical cyclone activity increases	Likely	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers, potential for population migrations, loss of property
Increased incidence of extreme high sea level (excludes tsunamis)[c]	Likely[d]	Salinisation of irrigation water, estuaries and freshwater systems	Decreased freshwater availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above

[a] See Working Group I Fourth Assessment Table 3.7 for further details regarding definitions.
[b] Warming of the most extreme days and nights each year.
[c] Extreme high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values of observed sea level at a station for a given reference period.
[d] In all scenarios, the projected global average sea level at 2100 is higher than in the reference period [Working Group I Fourth Assessment 10.6]. The effect of changes in regional weather systems on sea level extremes has not been assessed.

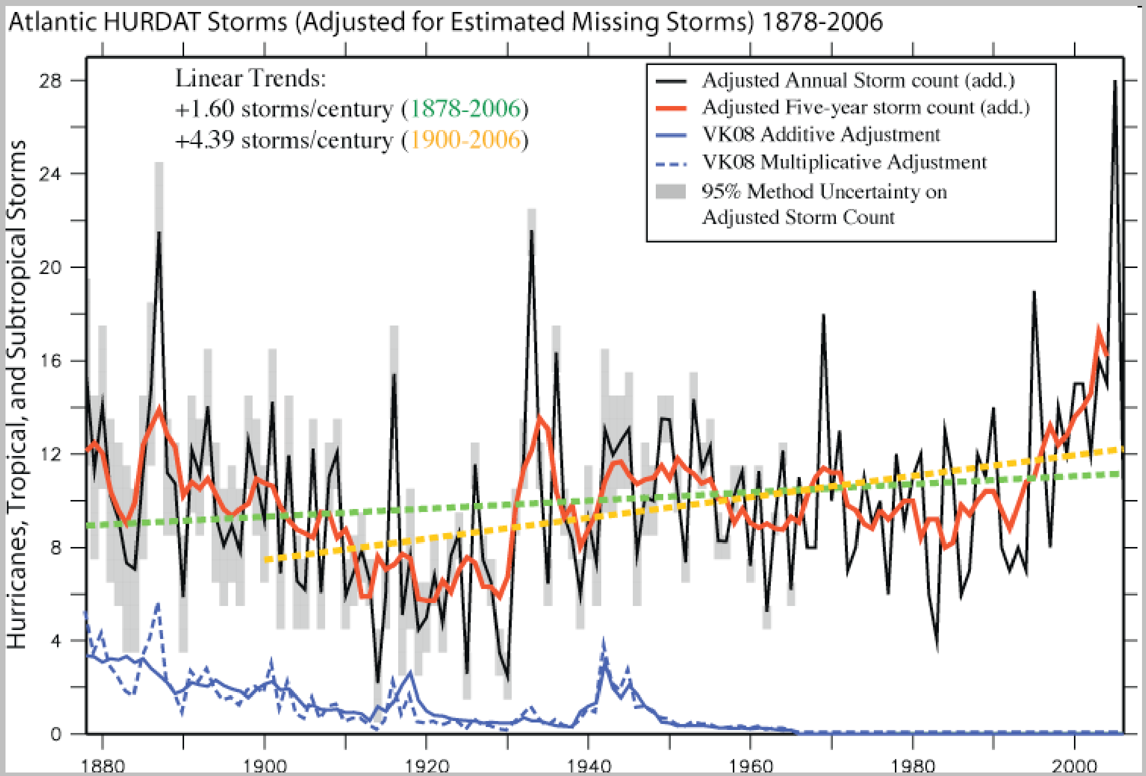
Table SPM.1. *Examples of possible impacts of climate change due to changes in extreme weather and climate events, based on projections to the mid- to late 21st century. These do not take into account any changes or developments in adaptive capacity. Examples of all entries are to be found in chapters in the full Assessment (see source at top of columns). The first two columns of the table (shaded yellow) are taken directly from the WorkingGroup I Fourth Assessment (Table SPM-2). The likelihood estimates in Column 2 relate to the phenomena listed in Column 1.*

Sea-level rise in Puerto Rico
Consistent with range of IPCC projections

Even a sea level rise of about one meter or less would put virtually all the major urban areas on the island in jeopardy.

Topography and urbanization in Jamaica is nearly identical.

Increase in number of Atlantic hurricanes?

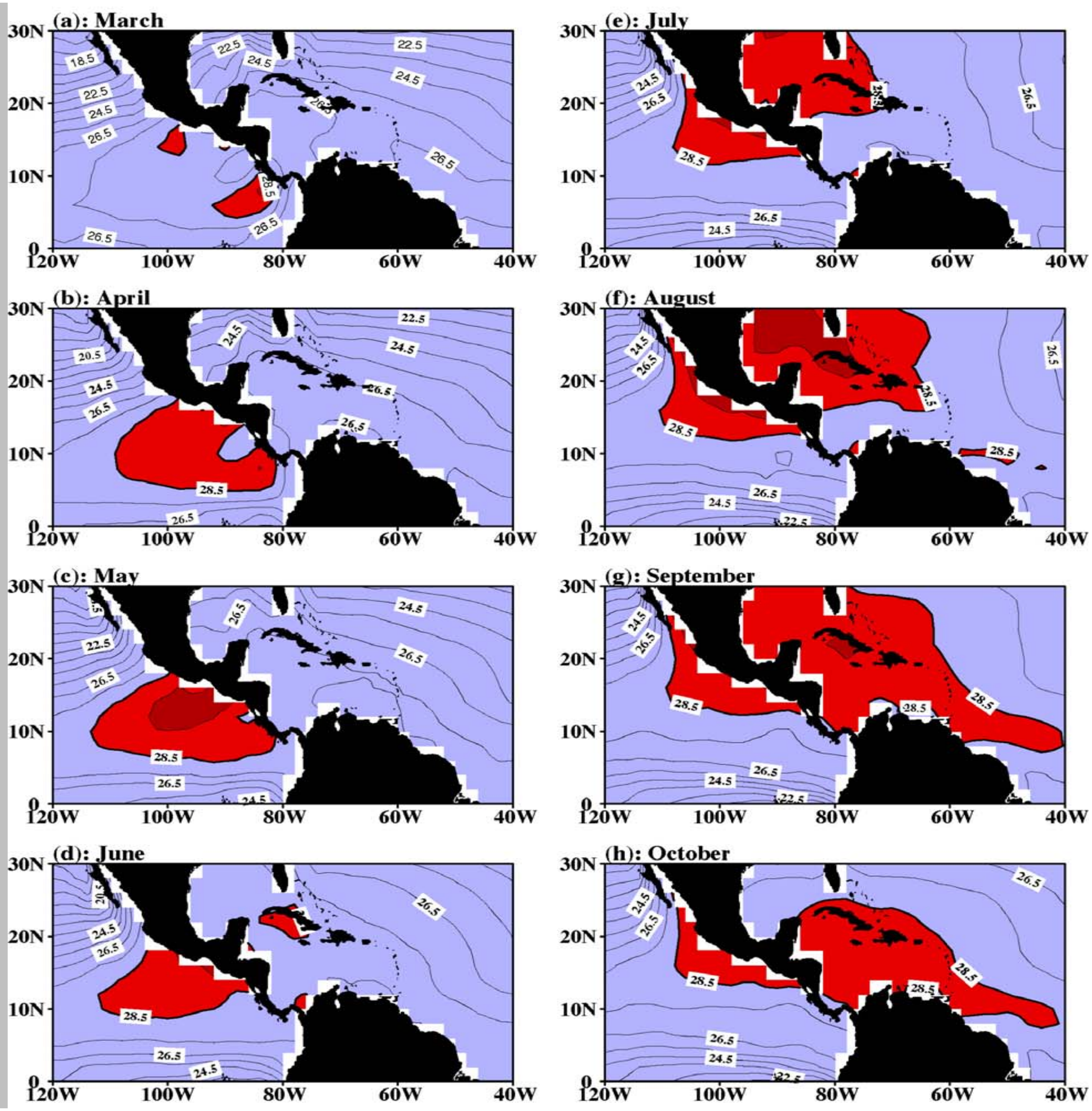


Vecchi and Knutson (2008)

Accounting for the uncertainties in the observations, there has been a long-term increase but it is not statistically significant.

Wang & Enfield (2001, *GRL*) named the Western Hemisphere warm pool (WHWP)

SST ≥ 28.5°C



Meteorological Factors Necessary to Generate an Intense Hurricane

Warm SSTs

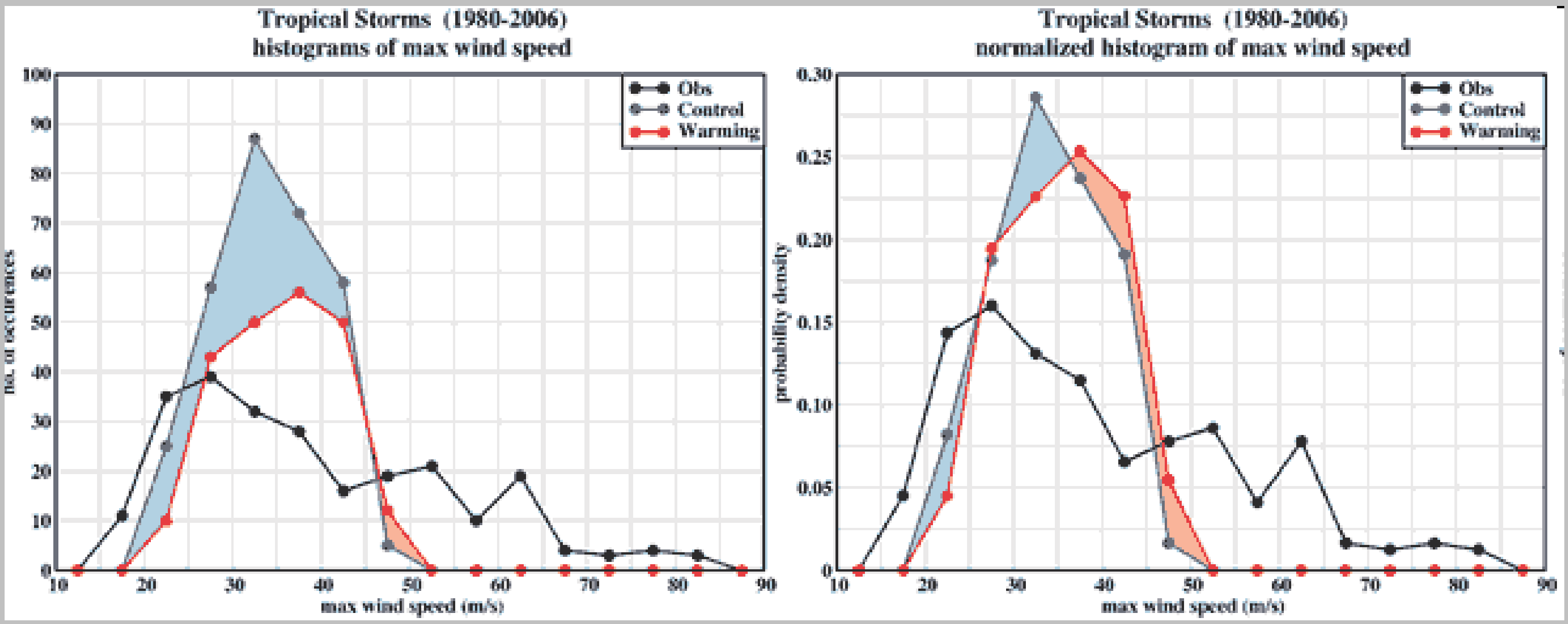
Low-vertical Wind Shear

Conditional Instability

Pre-existing disturbance

How climate change affects the atmospheric precondition factors is not so clear…

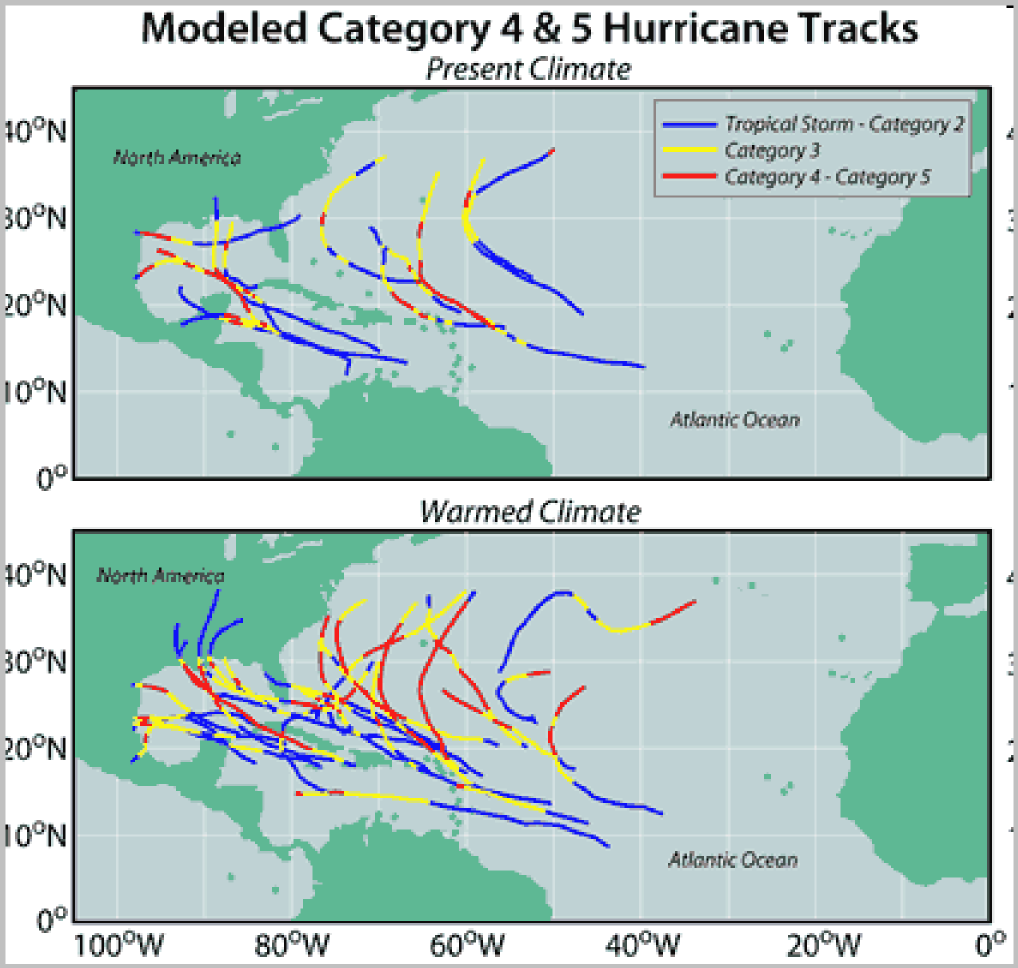
Results of high resolution mesoscale model simulations for Atlantic: control vs. warming (A1B)



Knutson et al. (2008)

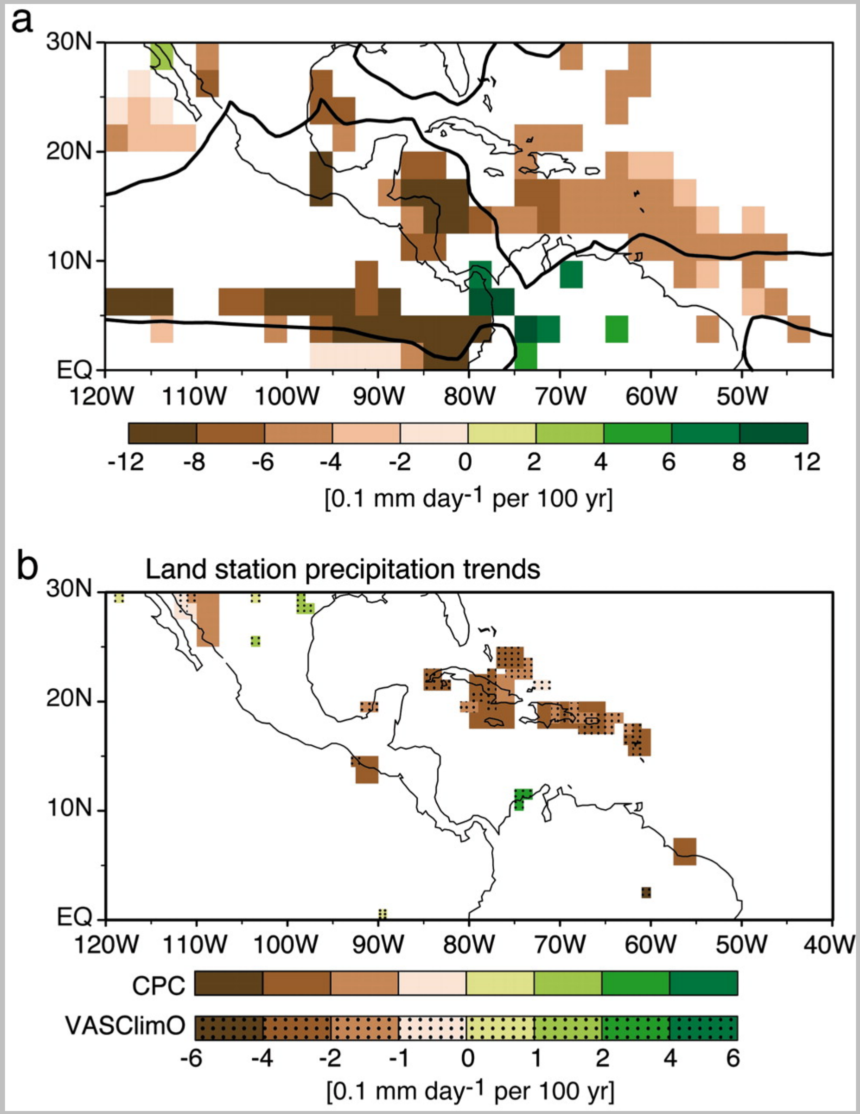
Overall number of simulated storms in warming scenario decreases but storms that do occur tend to be more intense, with higher rainfall rates and increased maximum winds.

Change in Intense Storm Tracks simulated with mesoscale models



Bender et al. (2010)

Observed Caribbean Drying in Summer (JJA)



CMAP precipitation (1979–2003)
(satellite-based)

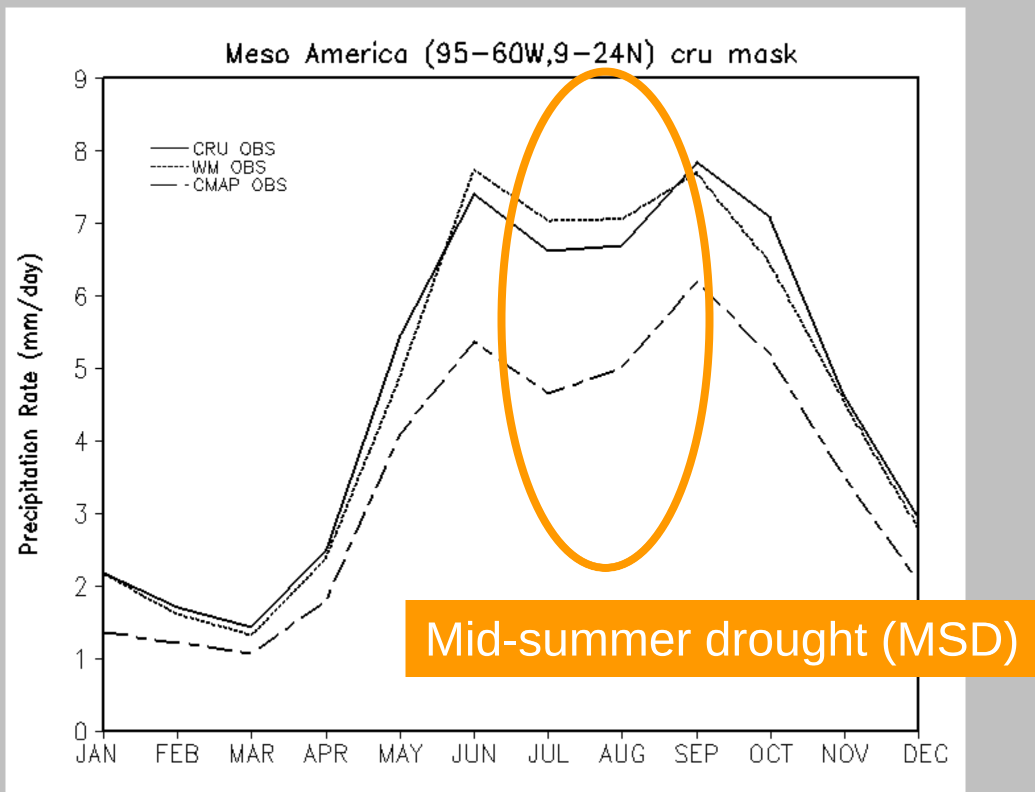
Yes, there is observed drying in summer.

Climate Prediction Center
Variability Analyses of Surface Climate Observations (1951–2000)
(gauge-based)

Neelin et al. (2006)

Slide courtesy of S. Raucher

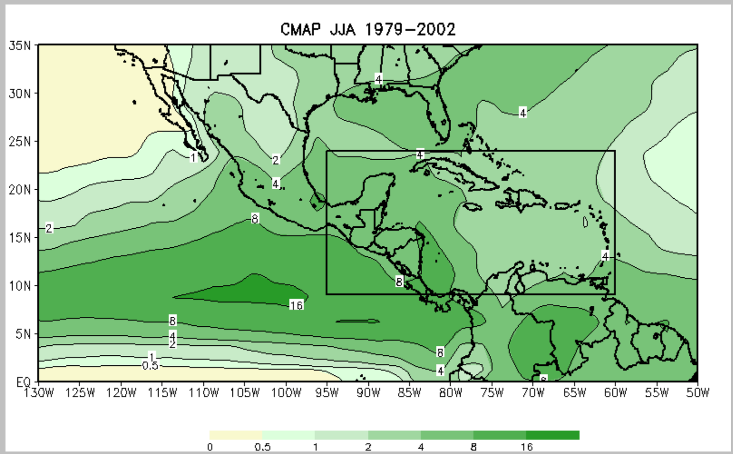
20th Century Precipitation (mm/day): Observations



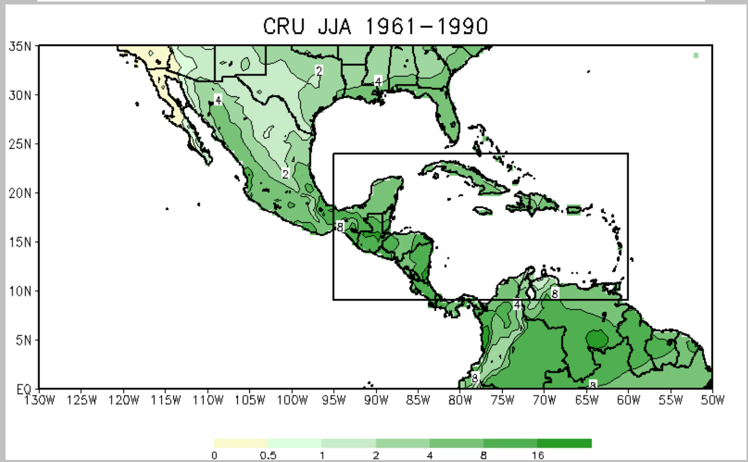
Month

CRU STATION OBS
WM STATION OBS
CMAP SAT OBS

OBS - Satellite JJA 1979-2002

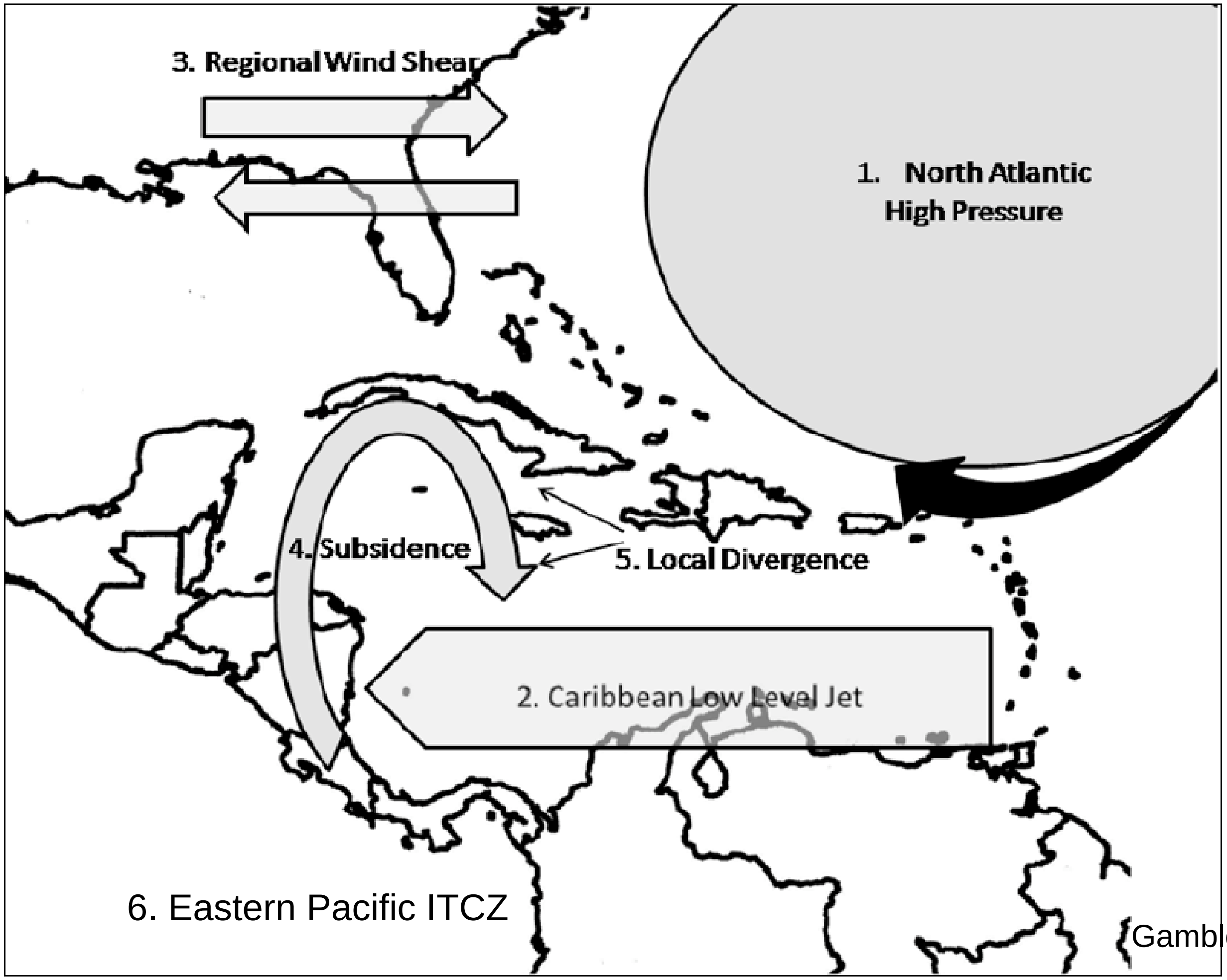


OBS - Station JJA 1961-1990



Slide courtesy of S. Raucher

Regional Climate Processes over Meso-America

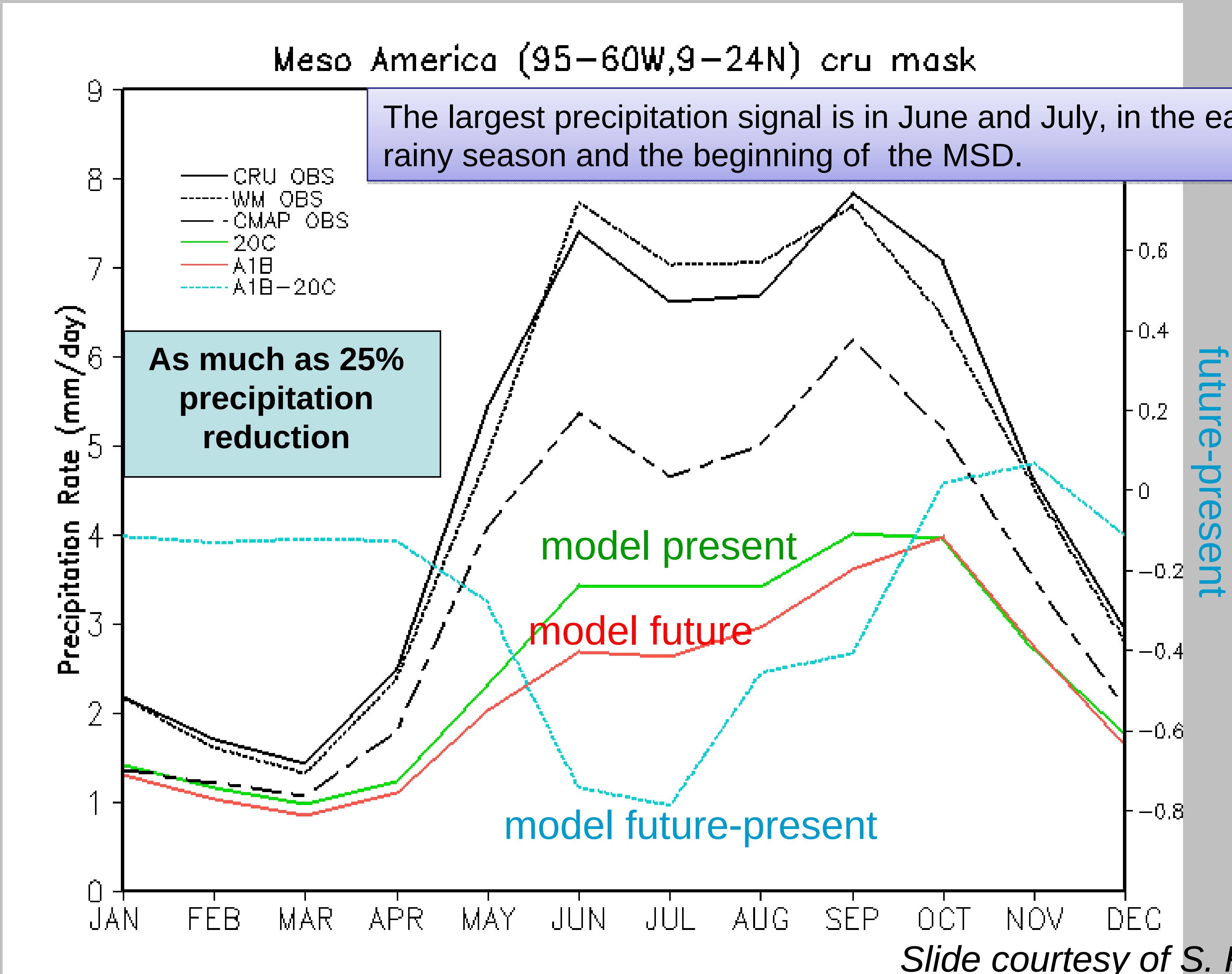


Gamble and Curtis (2008)

Figure 2 A new conceptual model of regional atmospheric processes causing the Caribbean midsummer drought and its associated spatial variability

Slide courtesy of S. Raucher

Precipitation Changes in the Annual Cycle



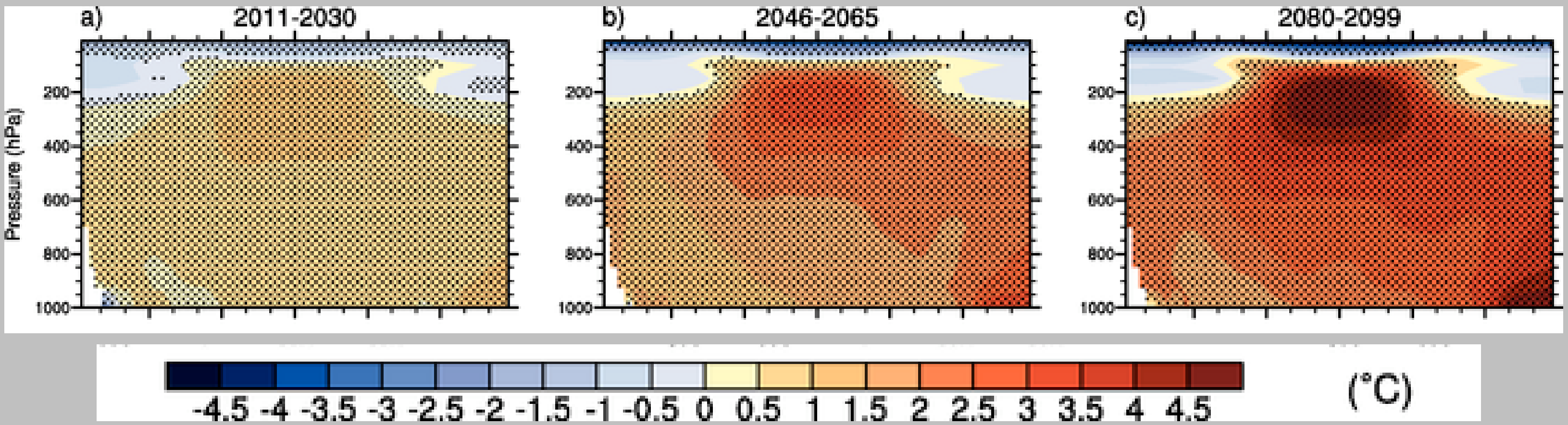
The largest precipitation signal is in June and July, in the early rainy season and the beginning of the MSD.

Slide courtesy of S. Raucher

Coherent large-scale circulation changes in the Caribbean in IPCC AR4 simulations

- *Stronger sub-tropical high and Caribbean low-level jet*: poleward expansion/intensification of subtropical high pressure cells associated with expansion of Hadley Circulation

- *Overall drying/southward shift in the ITCZ*: changes in tropical convection in a warmer world: greater static stability of tropics



Zonal means of change (A1B-20C) in atmospheric (top) temperatures (°C), shown as cross sections.
Anomalies are relative to the average of the period 1980 to 1999. (IPCC AR4, Figure 7)

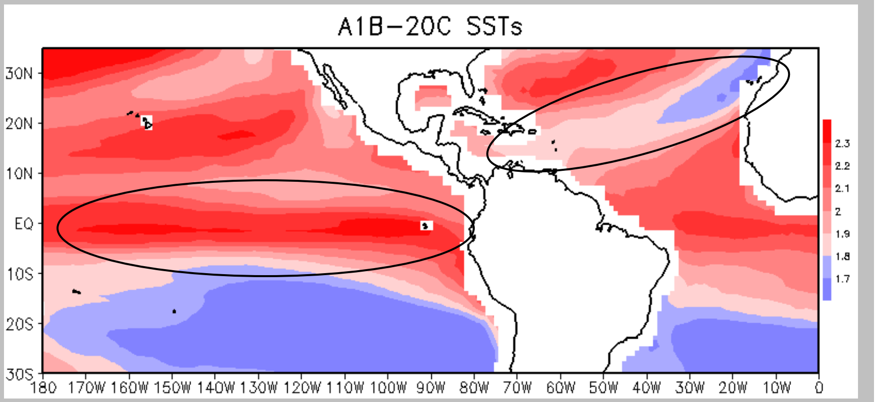
Slide courtesy of S. Raucher

Regional SST Patterns May Enhance the Drying

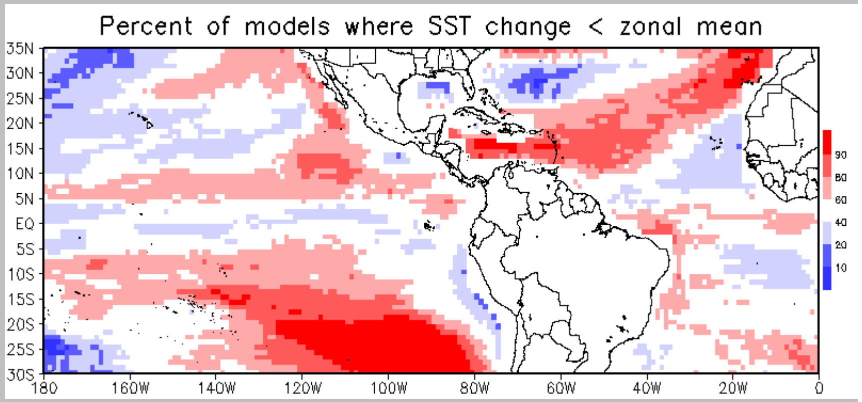
1) **Warming minimum over tropical North Atlantic**:
   (Vecchi and Soden, 2007, Leloup and Clement, 2008)
   + warm upper troposphere everywhere = greater stability over tropical Atlantic (thermodynamic)
   - Gill type response to off-equatorial heating anomaly (stronger sub-tropical high and Caribbean low level jet, reduced precipitation) (dynamic)

2) **El Niño-like mean state change of eastern tropical Pacific**:
   (e.g., Held and Vecchi 2007a,b)
   -El Niño can be associated with drying over Meso-America (southward position of ITCZ, inter-hemispheric SST gradient, stronger easterlies and shear)

Annual Average SSTs
Future - Present



Percent of Models where
SST change < Zonal Mean
June (month of max signal)



Slide courtesy of S. Raucher

Can a Regional Climate Model Yield Additional Insight?

Global Model or Atmospheric Reanalysis

Grid spacing of Hundreds of km

Dynamical downscaling

Limited area regional model

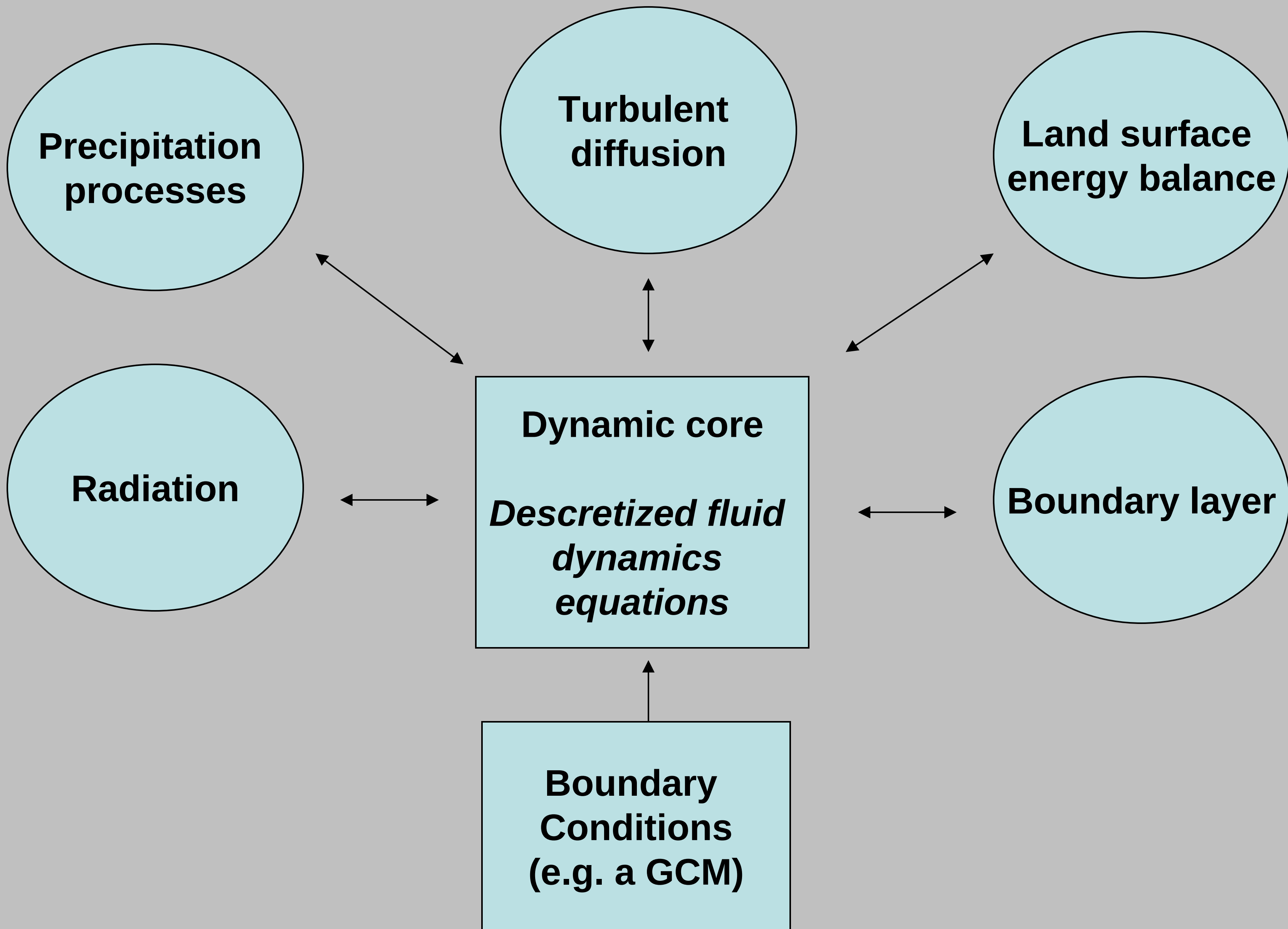
Grid spacing of Tens of km

<u>Value added by this process</u>:

•**Better representation of the land surface and atmospheric circulation**

•**Improved representation of atmospheric processes, like convective rainfall**

What comprises an regional atmospheric model?



Highlights of Regional Climate Model Study by Campbell et al. (2010) using PRECIS

J. D. CAMPBELL *et al.*

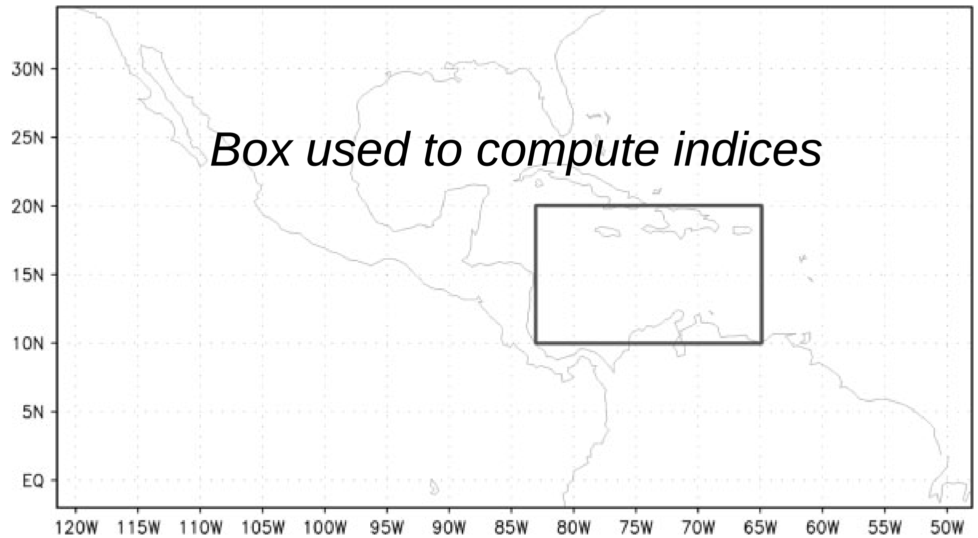


Figure 1. Map showing PRECIS domain over the Caribbean and adjacent Caribbean region. The box shows the Caribbean rainfall index domain as defined by Chen and Taylor (2002).

Grid spacing 50 km

Downscale one of the IPCC models (HadCM3) for various emission scenarios, climate control period late 20th Century and Climate Change period (late 21st century)

RCM Simulation of 20th Century Climate vs. Observed

J. D. CAMPBELL *et al.*

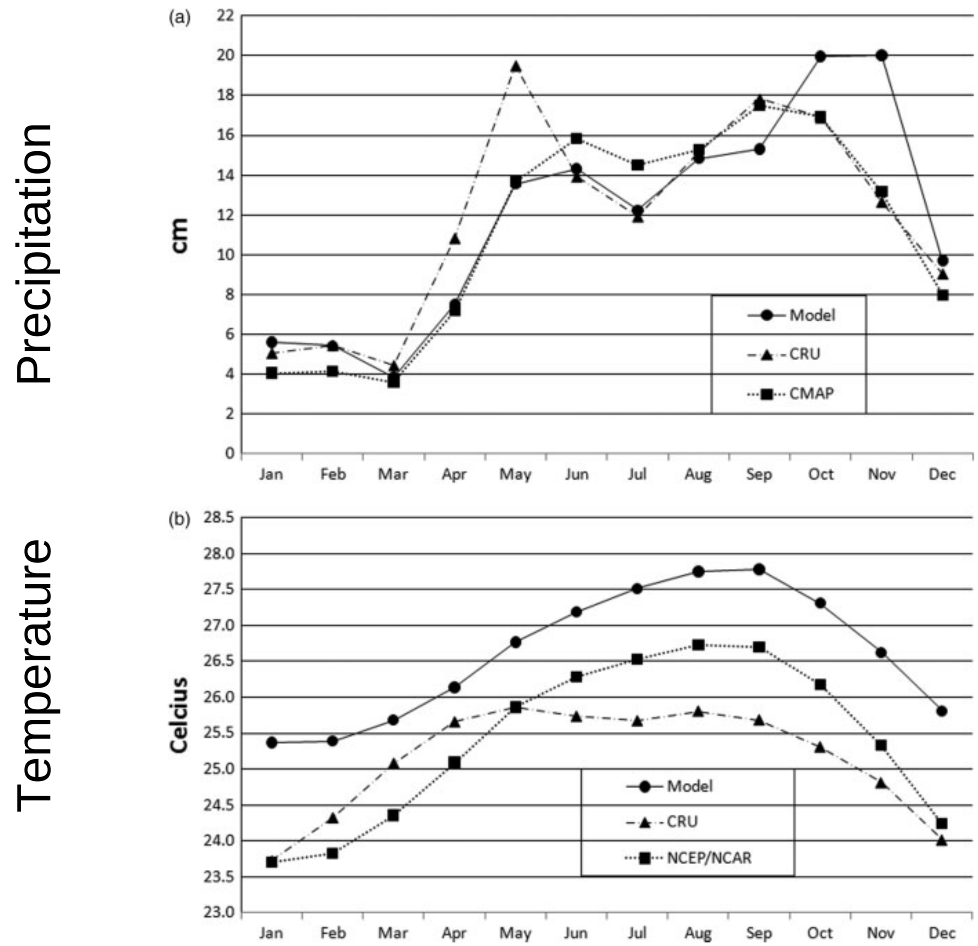
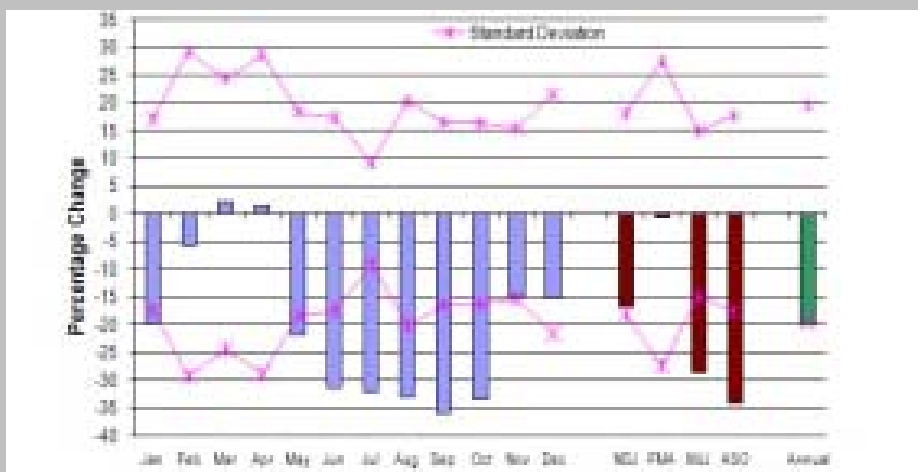


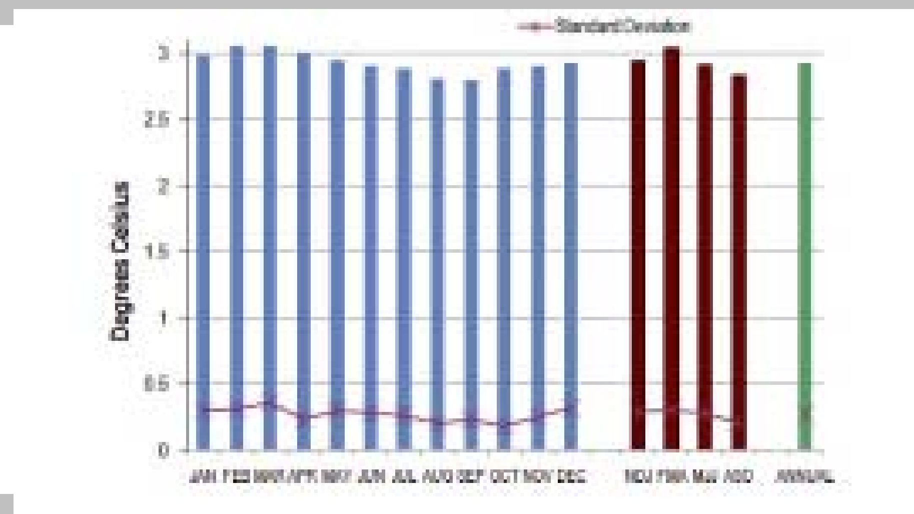
Figure 3. (a) Caribbean rainfall climatological time series, averaged over the area 10 °N–20 °N and 65 °W–83 °W, obtained from CMAP (dashed line with squares), CRU observations (dashed line with triangles) and PRECIS simulation (solid line with circles) for the period 1979–1990. Units are in cm. (b) Caribbean temperature climatological time series, averaged over the entire domain, obtained from NCEP–NCAR reanalysis (dashed line with squares), CRU observations (dashed line with triangles) and PRECIS simulation (solid line with circles) for the period 1979–1990. Units are in °C.

Regional Model Simulated Changes in Caribbean under A2 Emission Scenario

Precipitation



Temperature

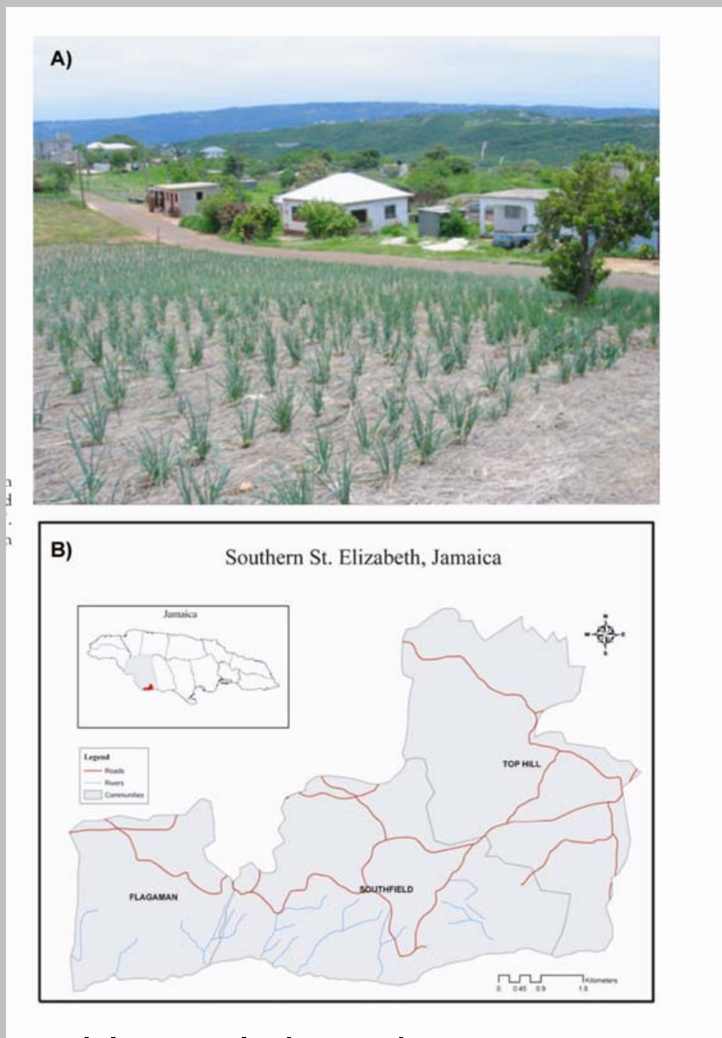


Maximum drying focused mid to late summer. Wetter farther north in winter.

Temperature increase of 3ºC year constant year round

Results very consistent with IPCC global model ensemble results shown earlier

Is climate change already impacting an agriculturally productive region in Jamaica?



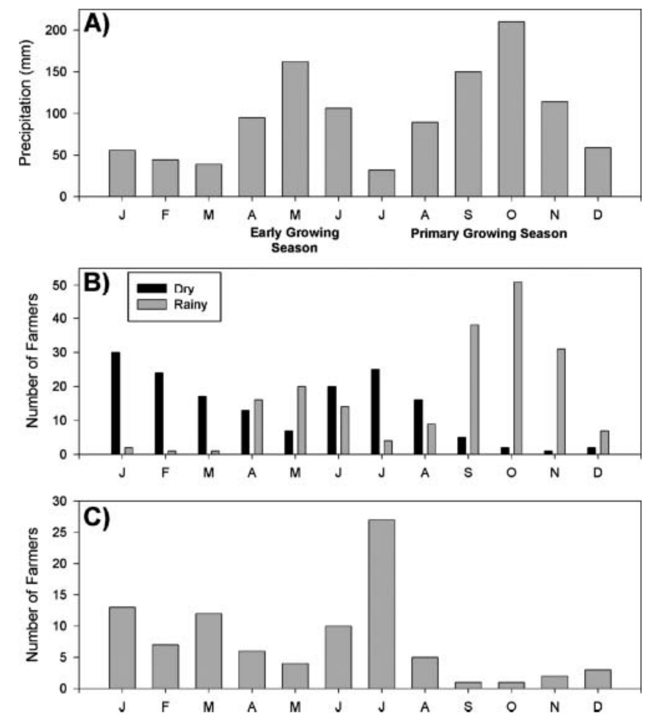
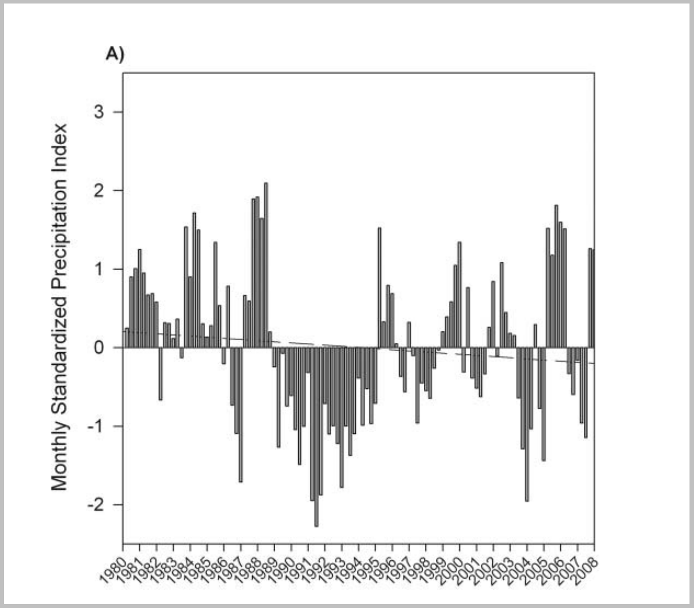


Figure 2. (A) Mean monthly rainfall (mm) for Southfield, St. Elizabeth Parish, Jamaica. (B) Frequency of farmers' perceptions of dry and rainy months. (C) Frequency of farmers' perceptions of the most severe dry month in terms of crop damage.

Gamble et al. (2010)

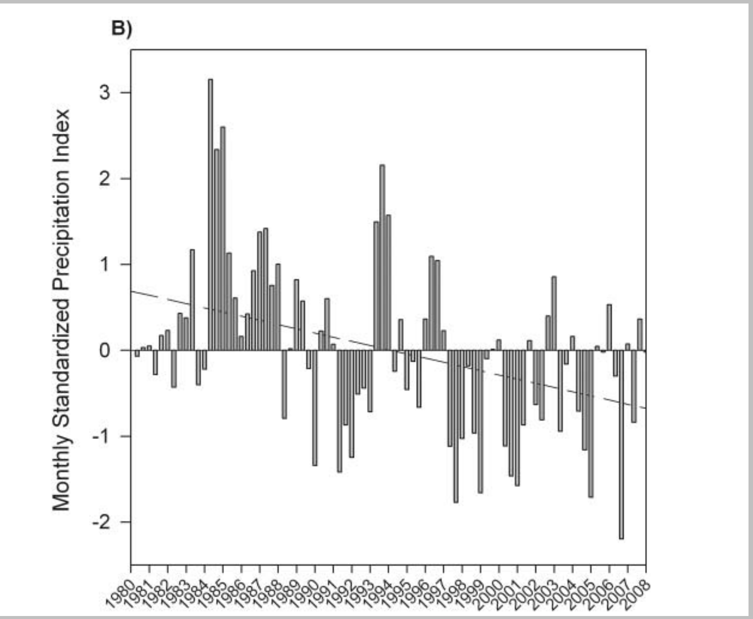
Change in Growing Season Precipitation in St. Elizabeth Parish (1980 – 2007)

Primary growing season (August – November)



Slight decrease.

Early growing season (April – July)



Statistically significant decrease. Affects growth of quick growing crops.

Anecdotal evidence from Jamaican farmers validates climate model projections!

Farmer's perceptions in St. Elizabeth Parish from Gamble et al. (2010)

"Farmer perceptions of increasing drought might reflect relative changes in the early (April–June) and principal (August–November) growing seasons. Specifically, many farmers commented in interviews that drought is becoming more prevalent in the early growing season as compared to the primary growing season. In particular, the farmers contend that the dry season before the early growing season is getting longer and the midsummer dry spell is starting sooner, in effect reducing the early growing season to one month, May."

If we accept climate change is happening and already affecting the Caribbean, what can be done?

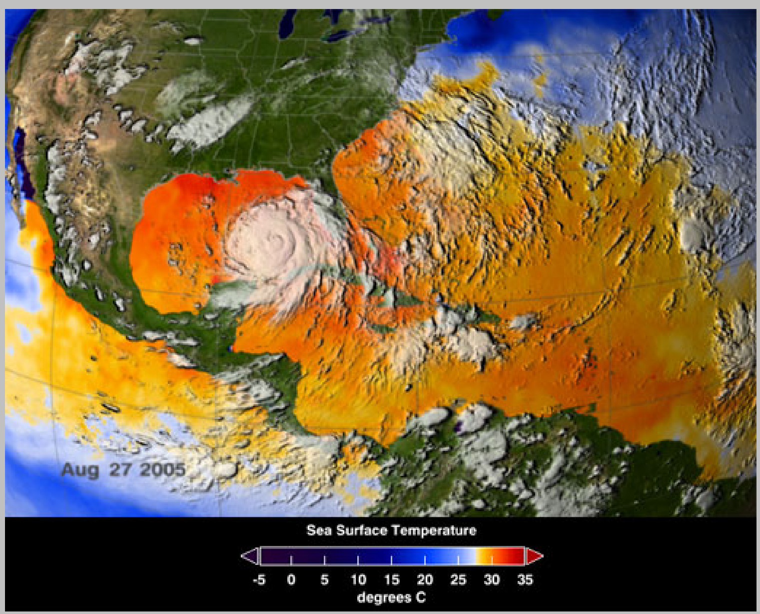
Climate change is here and cannot be stopped:

It can be potentially mitigated by greenhouse gas reductions, but only with very massive and coordinated socioeconomic changes on a global scale. This depends heavily on domestic politics within the biggest polluting countries—namely the United States, China, and India. Poorer, smaller countries have little or no influence in the process and any emissions reductions they make are insignificant.

Adaptation and preparedness should be the top priority:

Jamaica needs to quickly adapt infrastructure and economic and agricultural policies that adapt to the effects of climate change. Enhanced environmental monitoring to predict extreme events on daily and seasonal timescales are important.

The Continuously Operation Caribbean Observational Network: COCONet



Meghan Miller(1), Eric Calais(2), Mike Jackson(1), GuoquanWang(3), John Braun(4)

(1) UNAVCO

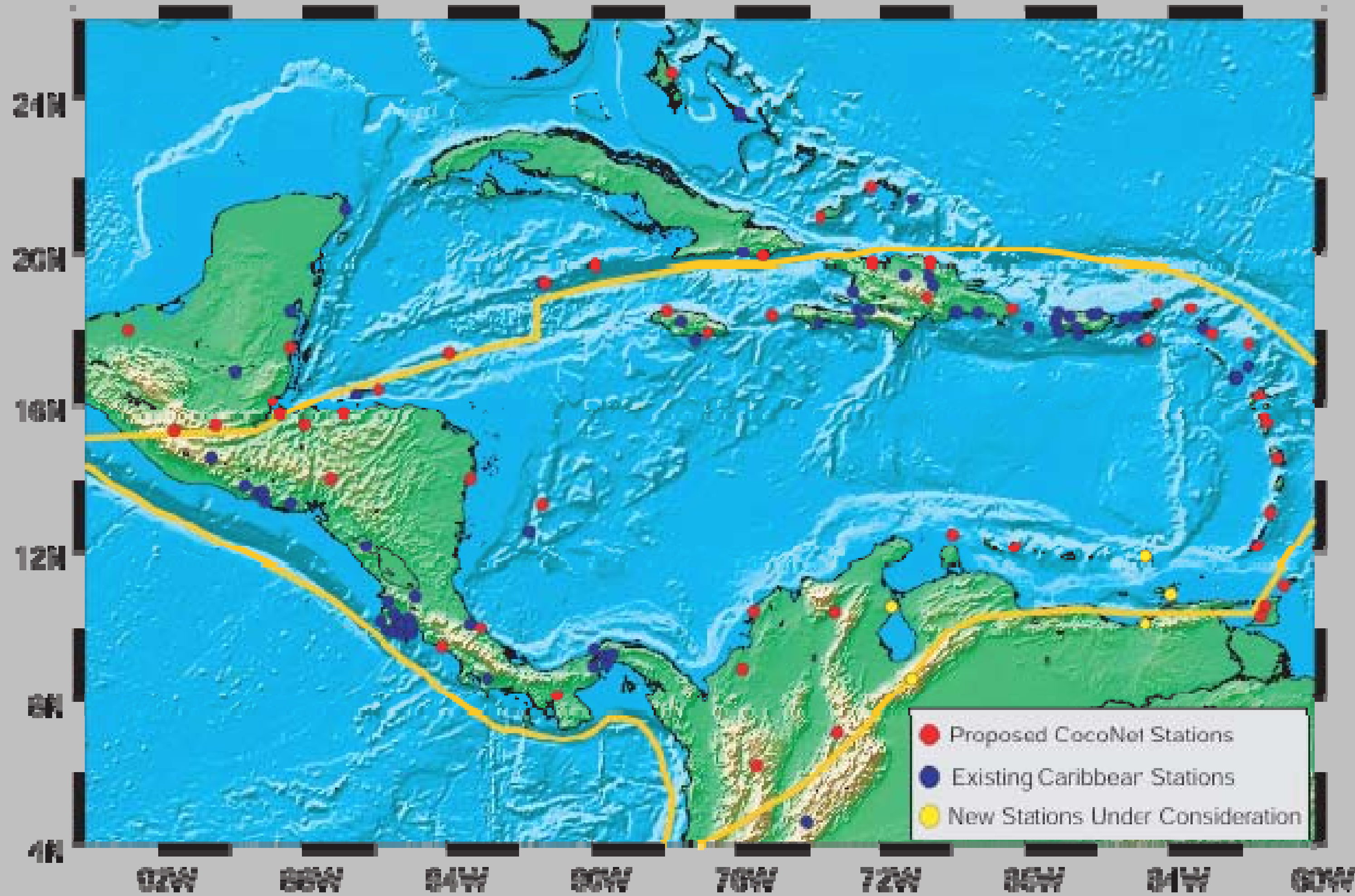
(2) Purdue University

(3) University of Puerto Rico at Mayaguez

(4) COSMIC/UCAR

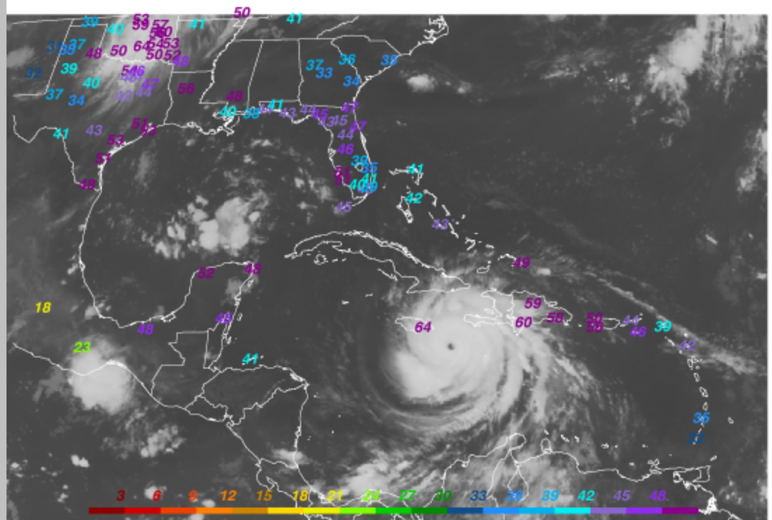
Caribbean GPS Installations

Proposed COCONet GPS Stations

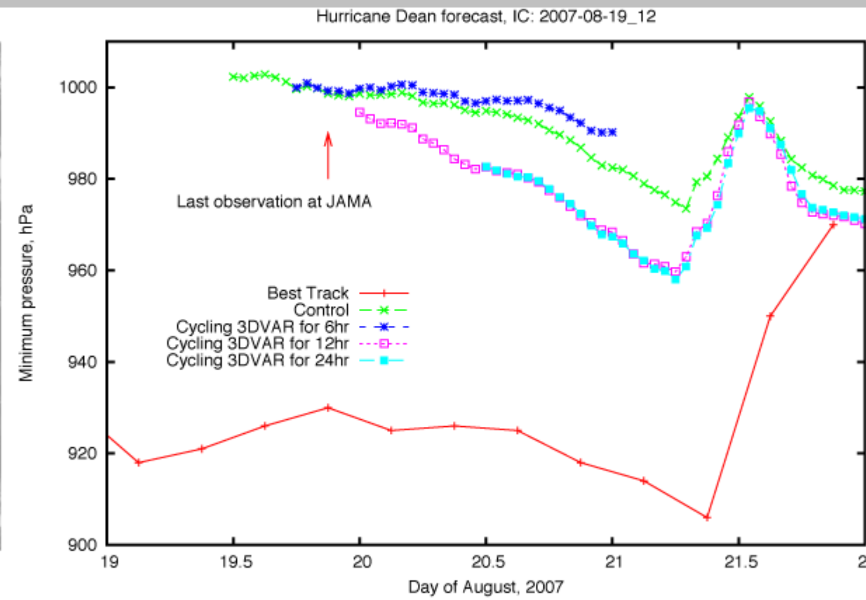


GPS Measured Water Vapor can Improve Hurricane Intensity Forecasts

Dean - 2007

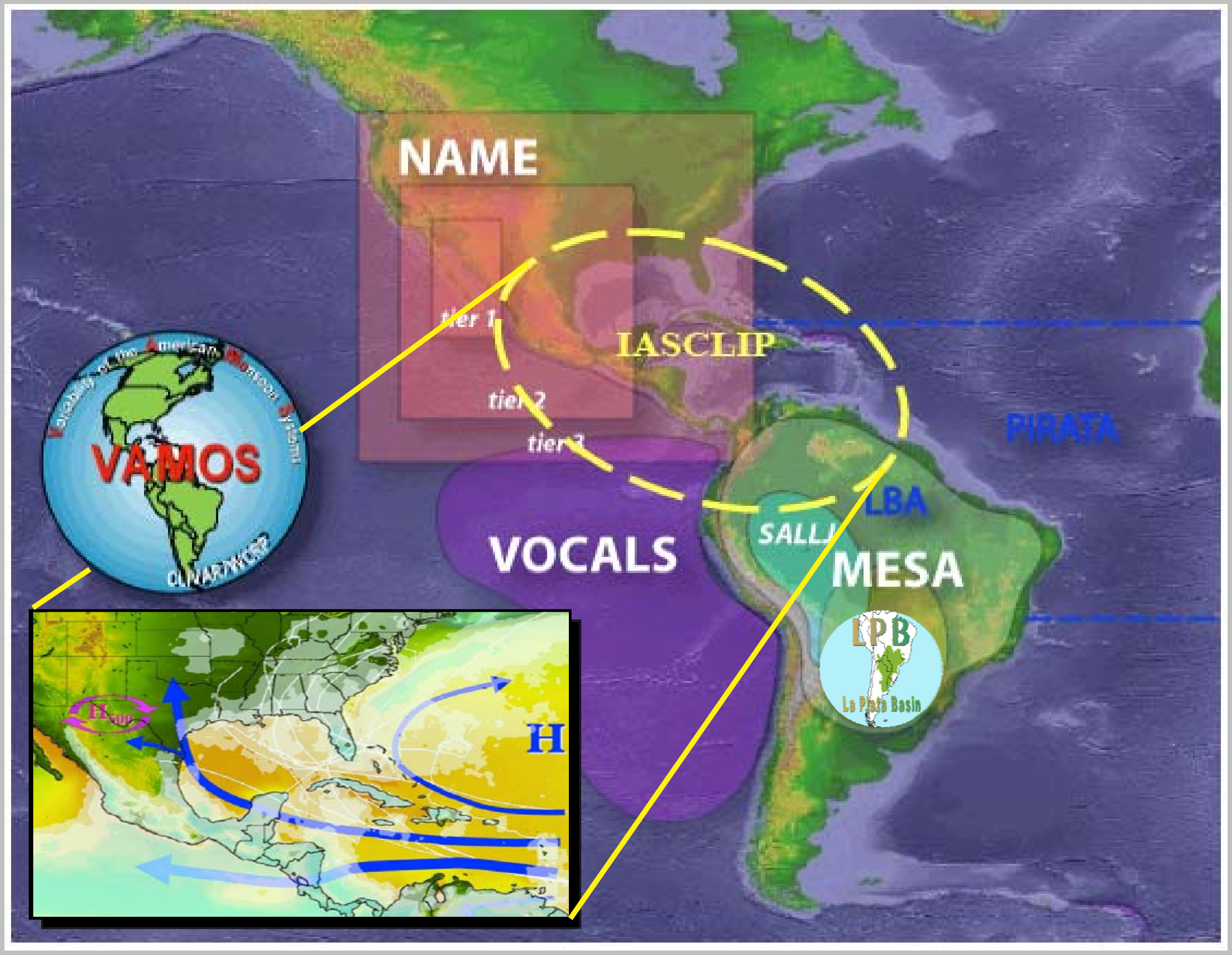


Suominet Precipitable Water Vapor 070819/1345



Assimilation of GPS water vapor into a high resolution atmospheric model causes a more intense hurricane to develop.

IASCLIP = Intra Americas Study of Climate Processes
CLIVAR-VAMOS Monsoon Program (FY09 - FY14)



What is **IASCLIP**?

- An integrated ocean-atmosphere research program focusing on the weather and climate impacts of the warm water pool in the Americas (Caribbean and East Pacific). IASCLIP seeks participation of regional governments and researchers.

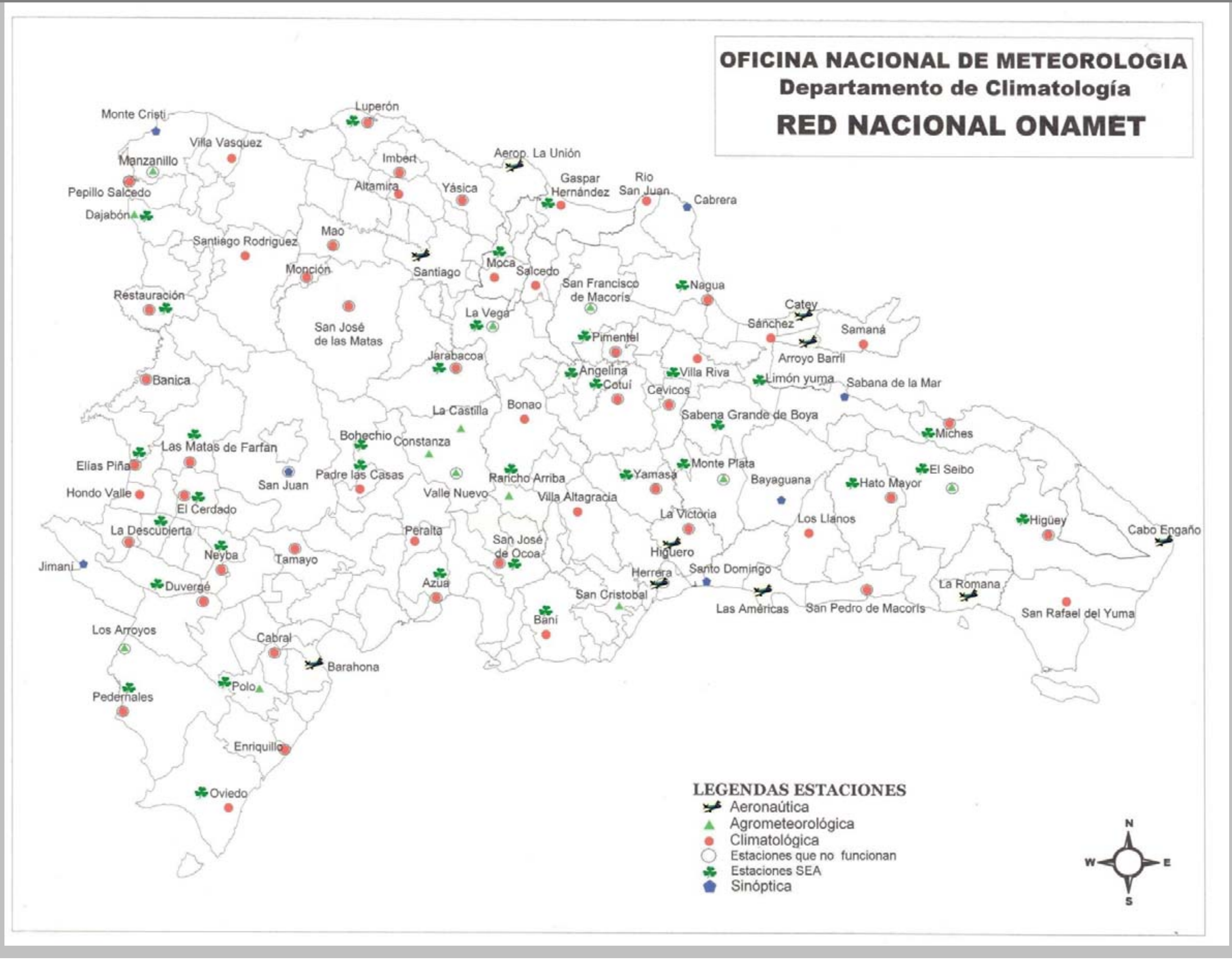
- The program seeks to enhance the observational network across the IASCLIP domain (atmospheric and oceanic).

- A major goal is the improvement of operational modeling of the warm water pool and associated atmospheric circulation across the IASCLIP domain.

- The program seeks to improve our understanding of the seasonal cycle and movement of the ITCZ across the IASCLIP domain. Emphasis will be on the transition of the monsoon systems between South and North America and associated teleconnections between these monsoons.

- The program seeks to improve our understanding and prediction of major weather and climate extremes within the region (e.g. tropical cyclones, flood events and regional drought). Integrating Societal responses to these phenomena will be an important component of IASCLIP.

Dominican Republic Proposed Rainfall Network for Precipitation Monitoring and Drought Detection



Summary and Conclusions

Conclusion of the IPCC is that climate change is real and very likely happening now. Most vulnerable sectors of society in Jamaica are already being affected, such as the farmers in St. Elizabeth Parish.

The Caribbean is projected to experience the following:

Increase in sea-level
Generally drier conditions, especially in early summer
More intense tropical storms and hurricanes

These are physically explained by a strengthening of the sub-tropical high, changes in sea surface temperature, and an increase in the strength of the Caribbean low-level jet. Use of a regional atmospheric model doesn’t substantially change the climate change projections.

Best course of action Jamaica can take is to adapt to climate change through enhanced environmental monitoring and by making the necessary infrastructual and socioeconomic changes.