# UNCTAD National Workshop Saint Lucia

24 – 26 May 2017, Rodney Bay, Saint Lucia

# “Climate Change Impacts and Adaptation for Coastal Transport Infrastructure in Caribbean SIDS”

# Climate Change Projections for the Caribbean and Implications for Air and Sea Ports

**By**

**Leonard Nurse**

University of the West Indies, Barbados

# Climate Change Projections for the Caribbean and Implications for Air and Sea Ports

Leonard A. Nurse
Faculty of Science and Technology
University of The West Indies, Cave Hill, Barbados

**UNCTAD National Workshop" Climate Change Impacts & Adaptation for Coastal Transport Infrastructure in Caribbean SIDS"**
**Castries, St. Lucia**
**May 24-26, 2017**

## Key Climate Risk Factors for Seaports and Airports in SIDS

- Increasing air $^{0}$T and SST → (i) thermal expansion of ocean surface (ii) greater *convection potential* over ocean
- Rising sea level and surge → (a) raise $H_2O$ levels (b) *high amplitude waves* and increased potential for damage
- Higher wind speeds→ increased storminess (IPCC AR5)
  - No clear trend in total projected storm numbers BUT *tropical cyclone intensity projected to increase*
  - *Frequency of the most intense storms* likely to increase substantially in some basins
  - Likely increase in both *global mean tropical cyclone maximum wind speed* and *rainfall intensity*

## *Representative Concentration Pathways Scenarios*

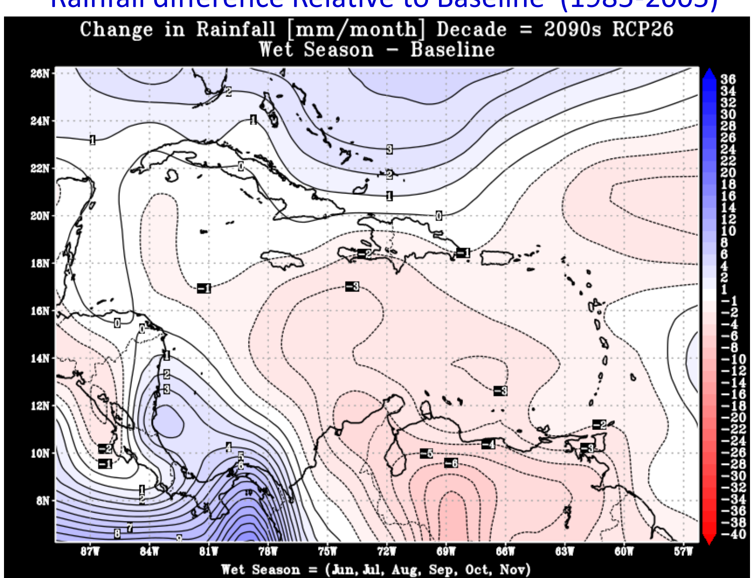
- The 4 RCPs are defined by the IPCC as follows:
- One *high* pathway → radiative forcing exceeds 8.5 W/m$^2$ by 2100 and continues to rise for some period thereafter;
- Two intermediate *stabilization* pathways → radiative forcing is stabilized at around 6.0 W/m$^2$ and 4.5 W/m$^2$ after 2100;
- One *low* pathway - where radiative forcing peaks at about 3 W/m$^2$ before 2100 and declines thereafter.

| RCP | Description |
|---|---|
| RCP8.5 | Rising radiative forcing pathway leading to 8.5 W/m$^2$(~1370 ppm $CO_2$e) by 2100. |
| RCP6 | Stabilization without overshoot pathway to 6 W/m$^2$(~850 ppm $CO_2$e) at stabilization after 2100 |
| RCP4.5 | Stabilization without overshoot pathway to 4.5 W/m$^2$(~650 ppm $CO_2$e) at stabilization after 2100 |
| RCP2.6 | Peak in radiative forcing at ~3 W/m$^2$ (~490 ppm $CO_2$e) before 2100 and then decline (the selected pathway declines to 2.6 W/m$^2$ by 2100). |

## Projected Wet Season Rainfall

RCP 2.6 CMIP5 Multi-Models

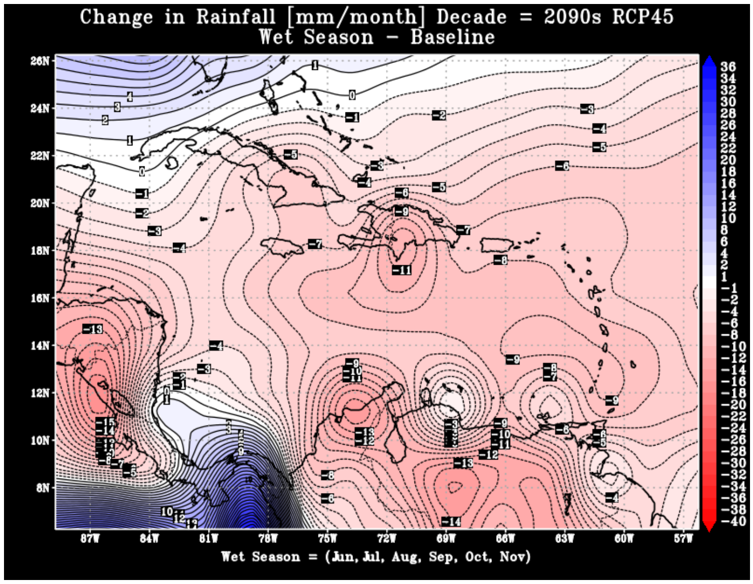
Rainfall difference Relative to Baseline (1985-2005)



## Projected Wet Season Rainfall

RCP 4.5 CMIP5 Multi-Models

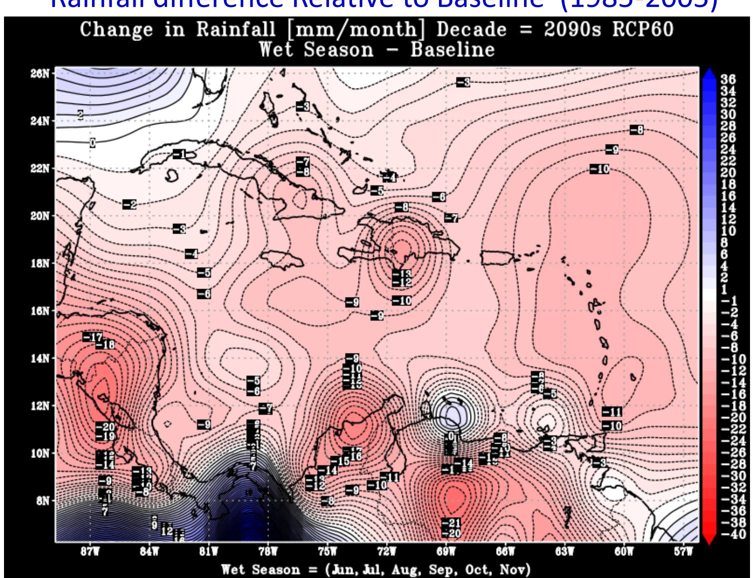
Rainfall difference Relative to Baseline (1985-2005)




## Projected Wet Season Rainfall

RCP 6.0 CMIP5 Multi-Models

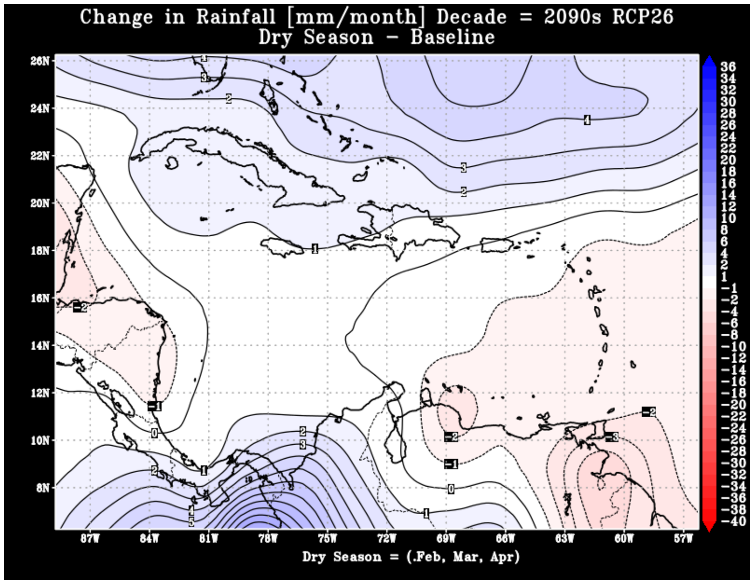
Rainfall difference Relative to Baseline (1985-2005)



## Projected Dry Season Rainfall

RCP 2.6 CMIP5 Multi-Models

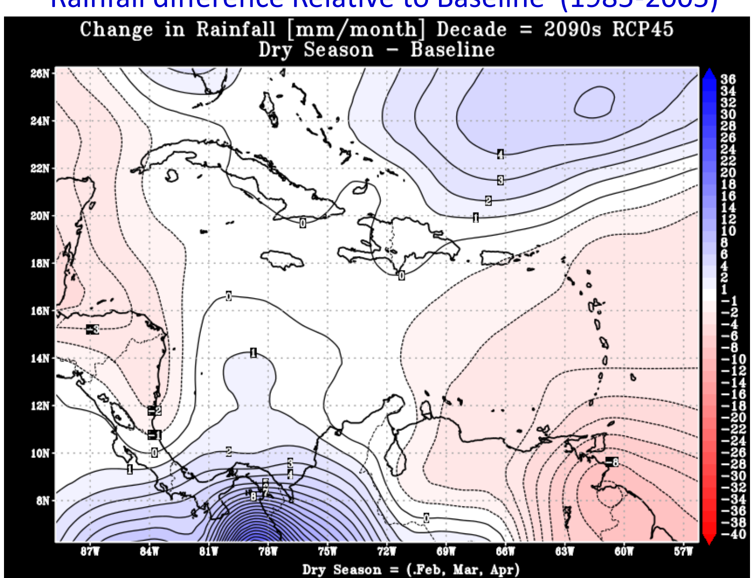
Rainfall difference Relative to Baseline (1985-2005)




## Projected Dry Season Rainfall

RCP 4.5 CMIP5 Multi-Models

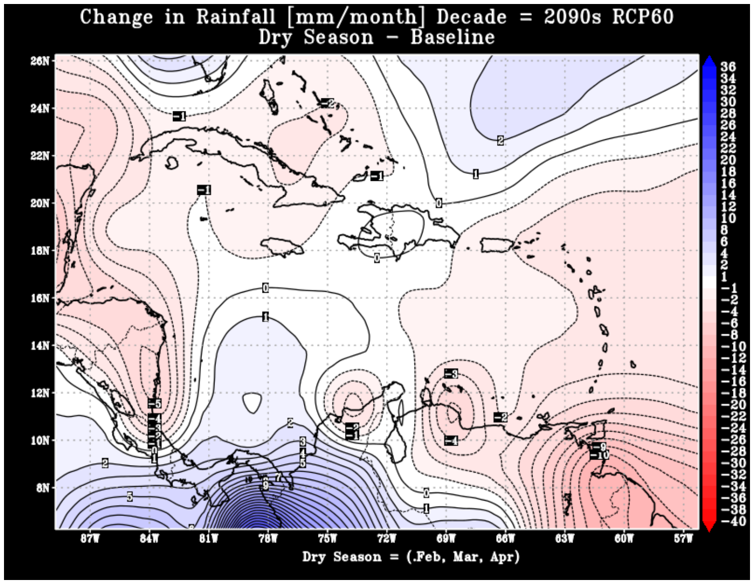
Rainfall difference Relative to Baseline (1985-2005)



## **Projected Dry Season Rainfall**

RCP 6.0 CMIP5 Multi-Models

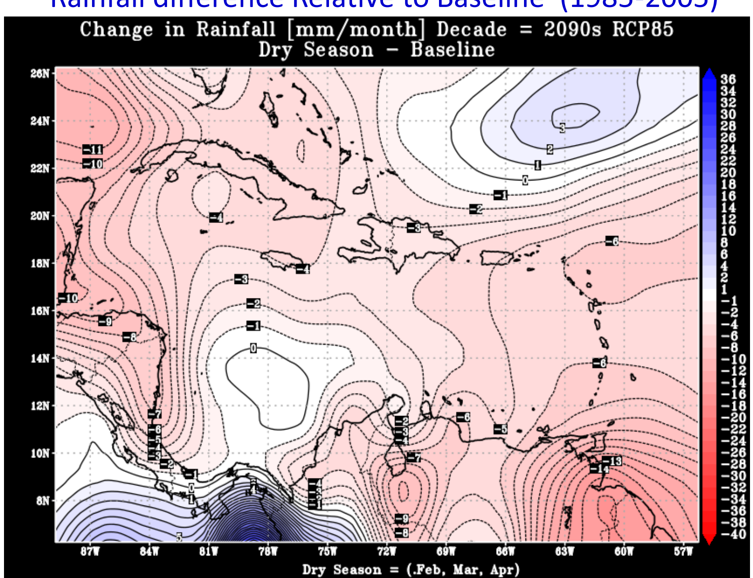
Rainfall difference Relative to Baseline (1985-2005)




## **Projected Dry Season Rainfall**

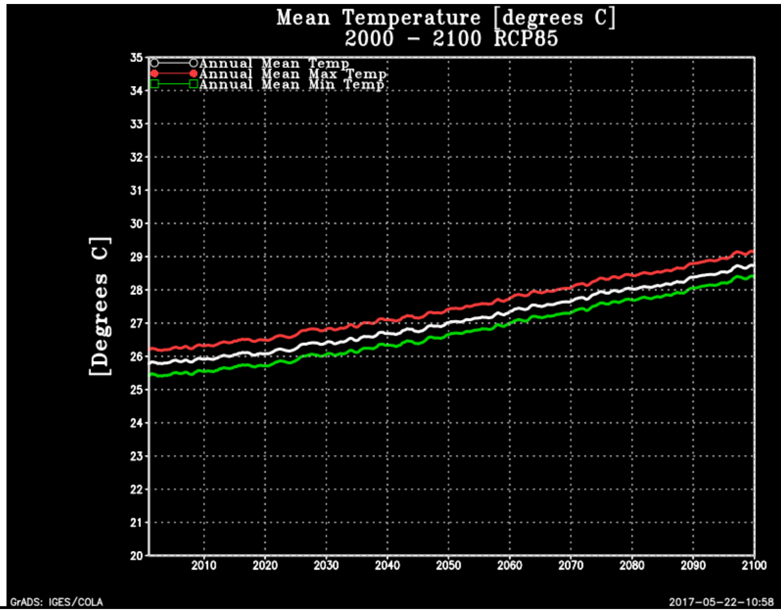
RCP 8.5 CMIP5 Multi-Models

Rainfall difference Relative to Baseline (1985-2005)



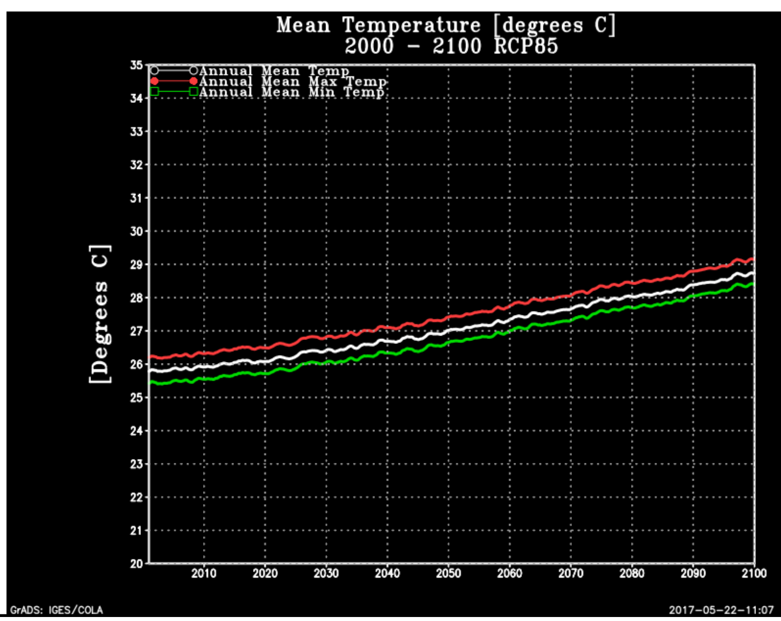
## Projected Temperature - St. Lucia

RCP 2.6 - 8.5 CMIP5 Multi-Models

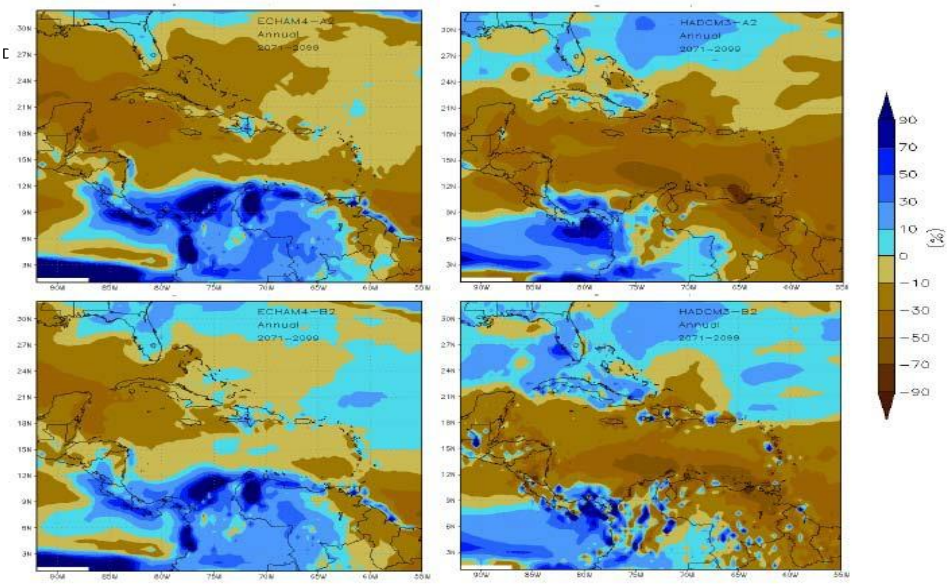



## Projected Temperature – Kingston, Jamaica

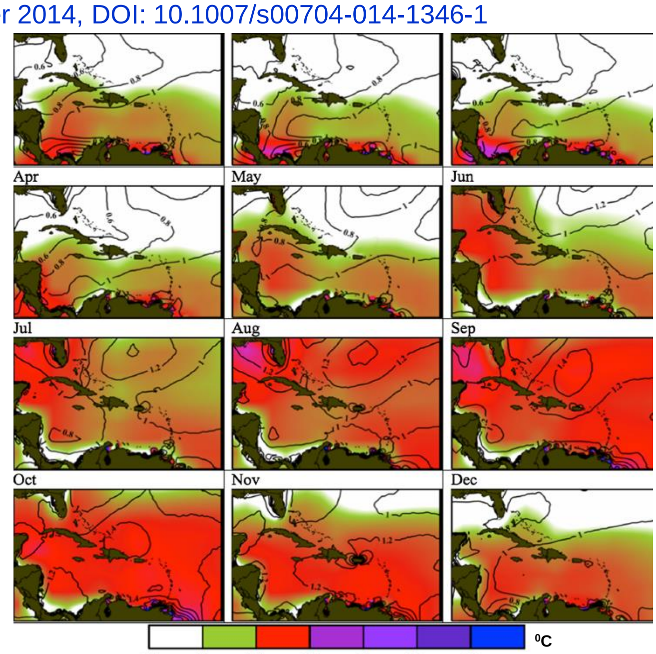
RCP 2.6 - 8.5 CMIP5 Multi-Models



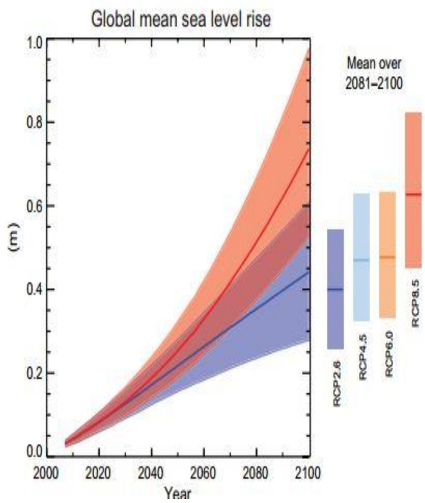
Drying trend between -25% and -30 % by end of Century. Drying far exceeds natural variability. Drier wet season likely (Taylor, 2011)




Source: Nurse and Charlery, 2015. *Theoretical and Applied Climatology*, December 2014, DOI: 10.1007/s00704-014-1346-1



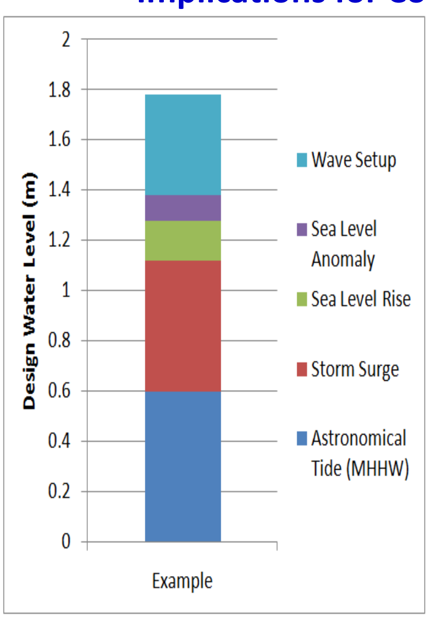
## 20$^{th}$ Century Observed SLR in SIDS Regions




- Tropical Western Pacific → rate of rise is almost 4 times the global average.
- Indian Ocean → rate of SLR as much as twice global average
- In **Caribbean** → rate of SLR generally higher than global average, ~ 1.8mm $^{yr-1}$.

► Guyana → is a special case - rate of SLR > twice the regional average. Why?

## Key Components of Water level Change: Implications for Coastal Air & Sea Ports




i. Astronomical Tide

ii Wave set up → increase in mean water level landward of breaker zone due to *flux of $H_2O$* at coast

iii Sea level anomaly → measure of the difference between short- and long-term MSL → *negative* and *positive* anomalies

iv Sea level rise

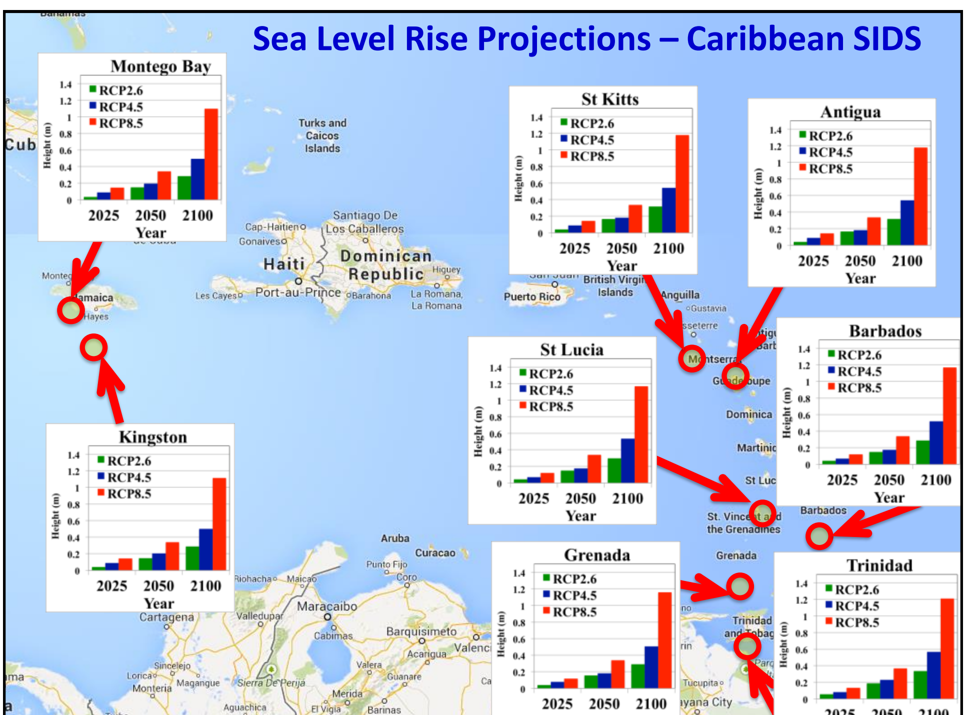
v Storm Surge

Note:

ii., iii. iv. and v. are *climate-sensitive phenomena*

## In coastal areas, quantitatively small changes have disproportionately large effects, e.g. storm surge

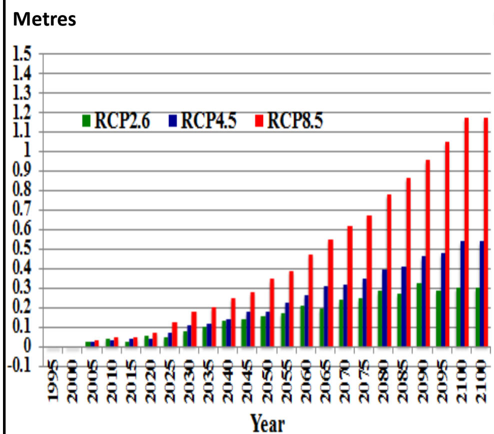
- Storm surge is associated with a rapid fall in barometric pressure, accompanied by strong *onshore* winds, as hurricane passes → '*Inverse barometer*' triggers a rapid elevation of $H_2O$ level.
- Surge generates large surface waves, leading to the 'piling up' of $H_2O$ at the coast.
- Relationship between reduction in pressure and $H_2O$ level is <u>not</u> linear:
  - Small drop in pressure can induce a significant rise in $H_2O$ level. For example, a 25.4 mm (1.0 in.) fall in the barometric pressure could produce a sea surface rise of approx. 33 cm (13.0 in.).

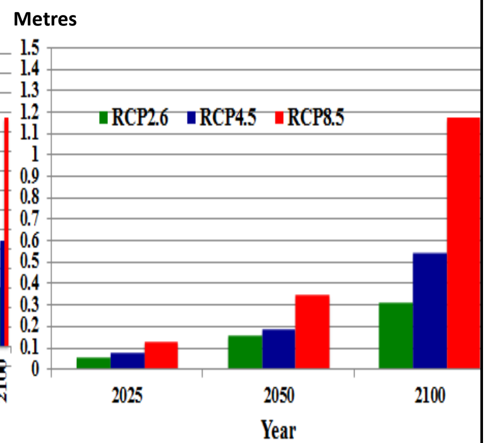


## St. Lucia Sea Level Rise Projections

**Data extracted for Grid Cells**

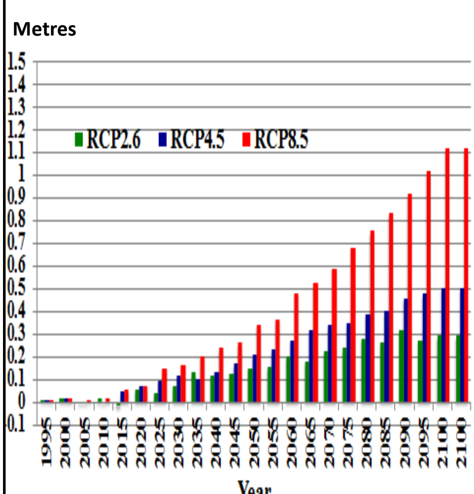
- **13.5° N, 60.5°W (Hewanorra Airport & Port Vieux Fort)**
- **14.5° N, 60.5° W (George F.L. Charles Airport & Port Castries)**

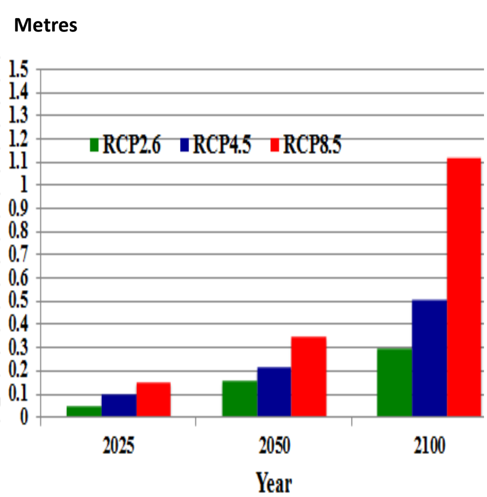



## Kingston, Jamaica, Sea Level Rise Projections

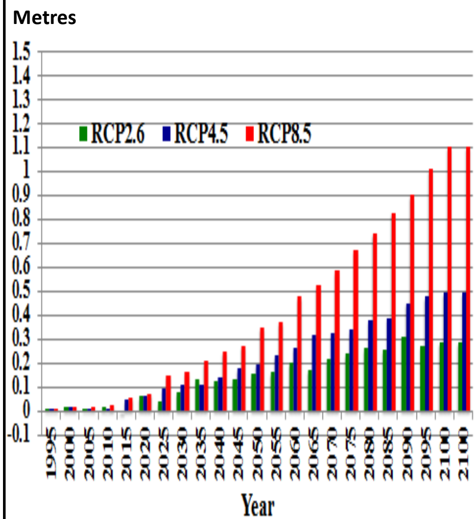
**Data extracted for Grid Cell 17.5° N, 76.5°W**
**(Norman Manley Airport & Kingston Container Terminal)**

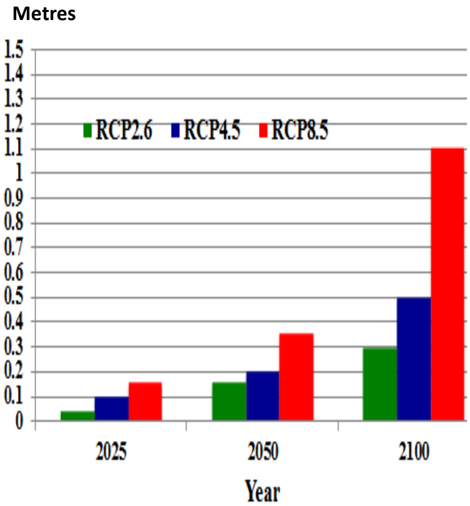


## Montego Bay (Jamaica), Sea Level Rise Projections

**Data extracted for Grid Cell 18.5° N, 77.5°W (Sangster Airport & Falmouth Cruise Port**




## Transport & Infrastructure Damage - Hurricane Lenny, Nov. 1999

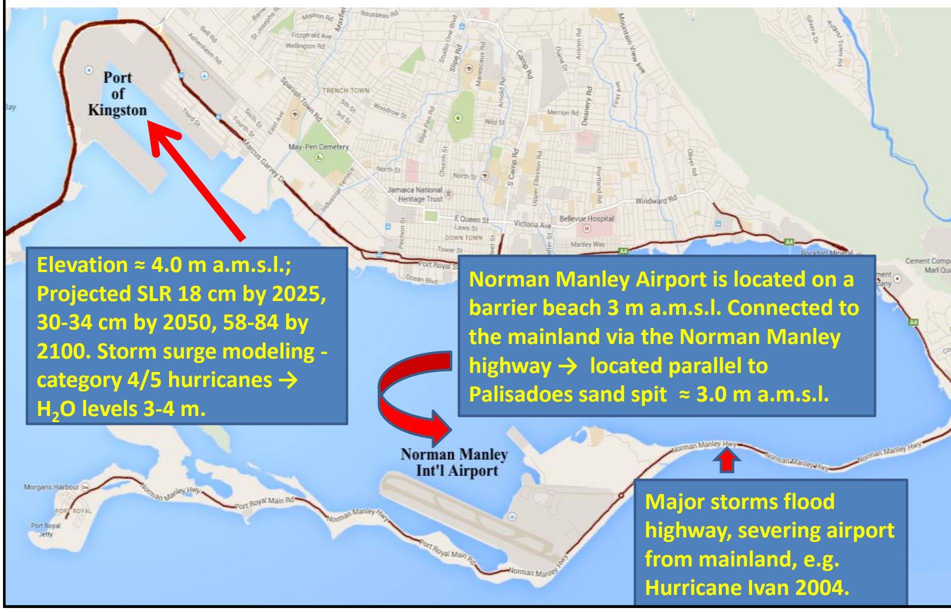

Northwestern & southern tip of the island most affected - landslides, severe beach erosion, airport flooded; 65% of Barbuda flooded, sanitary & water storage facilities overflowing; USD 51.3 M damages.

Damage & interruption at both airports
•Pottersville to Rockway highway closed; flooding at air & seaports; Roseau severed from petroleum storage facilities; west coast sea defenses breached; USD 21 M damages.

**Most damage at Soufriere , waterfront, Gros Islet, Anse La Raye, Choiseul; severe erosion on NW coast, housing & tourism damage; damage to seaport, flooding at airports; hospital cut off from town; USD 6.6 M.**

Seawall & other coastal defenses at Airport facilities damaged; structural failure and boat damage at St. George's Port; much damage to roads linking main settlements to air- & seaport; heavy damage to tourism plant; USD 94.3 M damages.

## Key Risk Factors for Port of Kingston and Norman Manley International Airport




## Palisadoes Highway Protection - The Main Access to Norman Manley International Airport, Jamaica



Repeated damage from the passage of storms over many decades. In 2004 Hurricane Ivan caused > 300 m of shoreline erosion → complete shutdown of airport and isolation of adjacent communities. A decision was taken to raise road to 3.2 m amsl (formerly 0.6 -1.0 m amsl) and build a coastal revetment, at cost > USD 65.3 M.

## Sample of Assets and operations At Risk: Air- and Seaports

- Climate-induced changes can cause serious damage to port infrastructure → major business interruption across entire supply chain:

◘ Tarmacs/runways & aircraft, fuel storage tanks

◘ Terminal facilities & associated throughput of passengers, goods and related services

◘ Utilities → $H_2O$, power supply, telecommunications

◘ Berths, bulkheads, seawalls, breakwaters

◘ Emergency response → e.g. fire and ambulance services

◘ Projected impacts could overwhelm existing capacities, e.g. storm and wastewater management systems

- Caribbean countries, like other SIDS, will be confronted by *increased exposure* and *related cumulative risks* at air & seaports

◊ Implications for *insurance*, *legal liability* & *operating costs*?

## Examples of Effects of Two Climate Variables on Air and Sea Port Operations

| Variable | Exposure Unit | Effects | Adaptation/Adjustment |
|---|---|---|---|
| **Air Temperature** | **Aircraft** | **Higher temperatures cause:**<br>• Lower air density<br>• Reduced lift generated by aircraft wings; slower climbs<br>• Effect on performance & efficiency | • Lower take-off weights/loads<br>• Longer runways |
| **More frequent Intense rainfall events** | **Terminals, warehouses & related facilities** | • Greater incidence of flooding<br>• Sewerage & drainage capacities exceeded, etc.<br>• Disruptions and down-time<br>• Business losses; possible loss of market share<br>• Higher maintenance & operation costs | • Redesign/retrofitting of infrastructure (e.g. drainage, sewerage) for greater capacity & efficiency<br>• Increased insurance/re-insurance to cover liabilities, demurrage, etc.<br>• Redesign of logistics, business plans, operations manuals, etc. |

**Kingston Container Terminal: Delivery of 4 Super Post-Panamax Ship-to-Shore Gantry Cranes, 2005 (Photo: Gleaner Newspaper)**

**Design Criteria for Port Cranes:**
**(ASCE-7 Standard: Minimum Design Loads….)**

● *Wind pressure* is a *critical determinant of tie-down uplift forces* acting on cranes during operation.

◙ Hurricane wind pressure based on 50-yr Mean Recurrence Interval (MRI)

◙ 3.0 $s^{-1}$ gust wind speeds, 10 m above ground

**Limitations**:

● Criteria based on historical data → may not reflect present conditions & not representative of future.

● Wind pressure varies as the square of the wind speed; errors increase when speed is converted to *wind pressure* → reliable wind data critical, e.g.

◙ 10% error in wind speed results in a 21% error in wind pressure calculation; and

◙ Error of *100% (or more) in tie-down uplift force*

[See i. McCarthy et al, 2009. Wind damage to dockside cranes: recent failures and recommendations. In *Lifeline earthquake engineering in a multi-hazard environment*, 1-12;
ii. Frendo, F., 2016. Gantry crane derailment and collapse induced by wind load. *Engineering Failure Analysis* 66, 479-488].

## Building Resilience at Ports – The Necessity for Adaptation in SIDS

- Past global GHG emissions & current trajectory guarantee that warming of atmosphere & oceans, and SLR will continue for decades (‘*climate inertia*’ → volume of GHGs already emitted).
- Notwithstanding proposed INDCs → no evidence that a binding post-Kyoto agreement will eventuate in Paris in December 2015.
  - ◘ Air- and seaport operations face heightened risks. For SIDS, risks are greater → almost total dependence on these facilities for imports and exports.
  - ◘ Air- and seaport infrastructure represent major investment → amortized over medium-to-long periods, e.g. minimum of 25-30 years, in some cases as many as 50+ years → fall within the timeframe of current climate change projections.

## Planning Adaptation at Air and Seaports – Constraints for SIDS

With few exceptions, '*protection*' of existing infrastructure and '*accommodation*' are the only practical responses available to most SIDS for the following reasons:

- Limited opportunities for relocation away from vulnerable areas → constraint of sheer physical size
- Central role of air and sea ports in these small, highly open economies
- Scarce/insufficient resources to replicate such high cost facilities ⟶ useful life of terminals, runways, taxiways, parking aprons etc. is on average minimum of 30 years.
- As in other jurisdictions , protection and accommodation strategies will therefore have to contemplate a suite of actions involving *infrastructure*, *technological*, *regulatory* and *change management* components.

## Examples of Potential Response Strategies for Air & Seaports in SIDS

| | |
|---|---|
| **Infrastructural /Engineering** | **Enhance the structural integrity of critical facilities including sea defenses, berths, mooring facilities, runways, parking aprons etc, based on design criteria that reflect changing wind, sea level and wave conditions; recalculation of return periods for major events such as hurricanes and floods, so that more resilient structures can be engineered → Caribbean** |
| **Technological** | **Invest in more climate-resilient technologies and equipment in expansion & upgrade programmes, e.g. solar photovoltaics to generate electricity more efficiently for both operations and administration, e.g. Airport at Oranjestad, Aruba; 451-kW PV system at St. Thomas Airport, USVI** |
| **Planning & Development** | **Internal capacity building and re-training that recognizes the magnitude and implications of the threat; building of *redundancy* into critical operations, wherever feasible; off-site warehousing and storage in less vulnerable areas, etc.** |
| **Management Systems** | **Various operational systems need to '*mainstream*' climate change considerations into their procedures, e.g. '*shut down*' and '*start up*' operations; emergency protocols and evacuation; environmental management systems; occupational safety and health protocols, etc.** |
| **Insurance** | **Some risks cannot be avoided ⟶ must be insured by third parties; In many Caribbean SIDS ⟶ collaboration among port management, climate scientists and insurance providers will provide a basis for more reliable quantification of *exposure* and *risks* that must be covered.** |

# Thank You

leonard.nurse@cavehill.uwi.edu
http://cavehill.uwi.edu/cermes