UNCTAD National Workshop Jamaica

30 May – 1 June 2017, Kingston, Jamaica

"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

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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

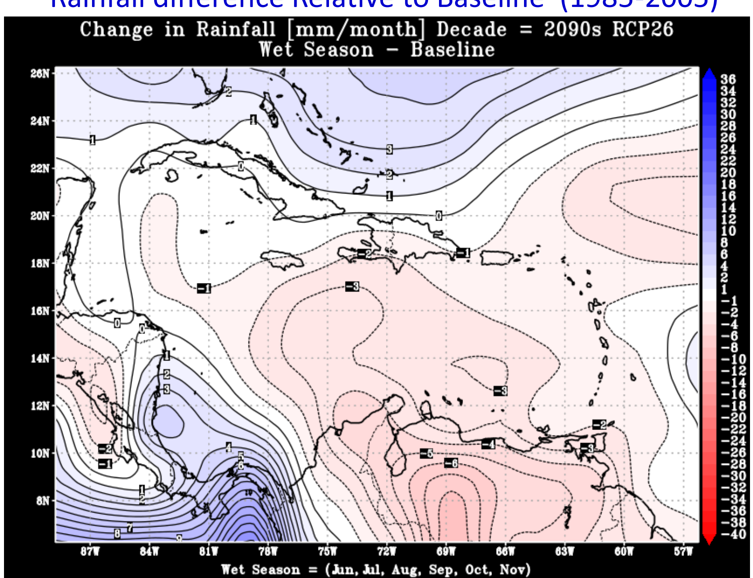
- The 4 RCPs are defined by the IPCC as follows:
- One *high* pathway → radiative forcing exceeds 8.5 W/m^2 by 2100 and continues to rise for some period thereafter;
- Two intermediate *stabilization* pathways → radiative forcing is stabilized at around 6.0 W/m^2 and 4.5 W/m^2 after 2100;
- One *low* 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_2e) by 2100.
RCP6	Stabilization without overshoot pathway to 6 W/m^2(~850 ppm CO_2e) at stabilization after 2100
RCP4.5	Stabilization without overshoot pathway to 4.5 W/m^2(~650 ppm CO_2e) at stabilization after 2100
RCP2.6	Peak in radiative forcing at ~3 W/m^2 (~490 ppm CO_2e) 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

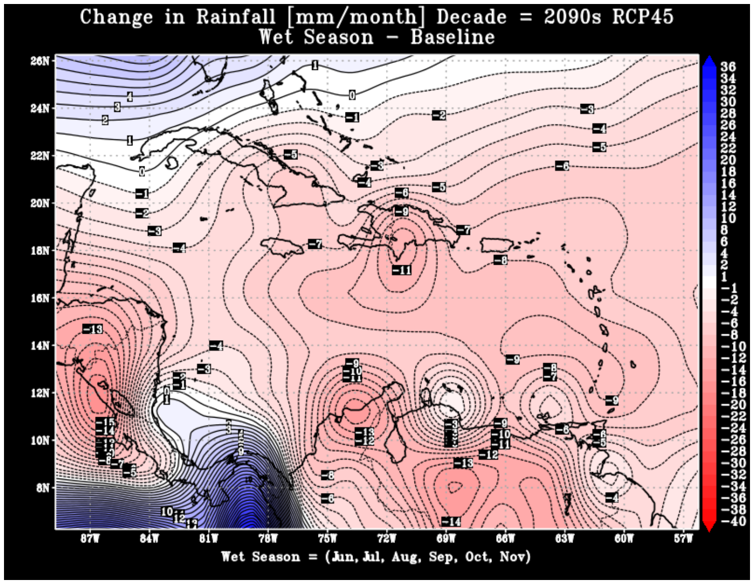
Rainfall difference Relative to Baseline (1985-2005)



Projected Wet Season Rainfall

RCP 4.5 CMIP5 Multi-Models

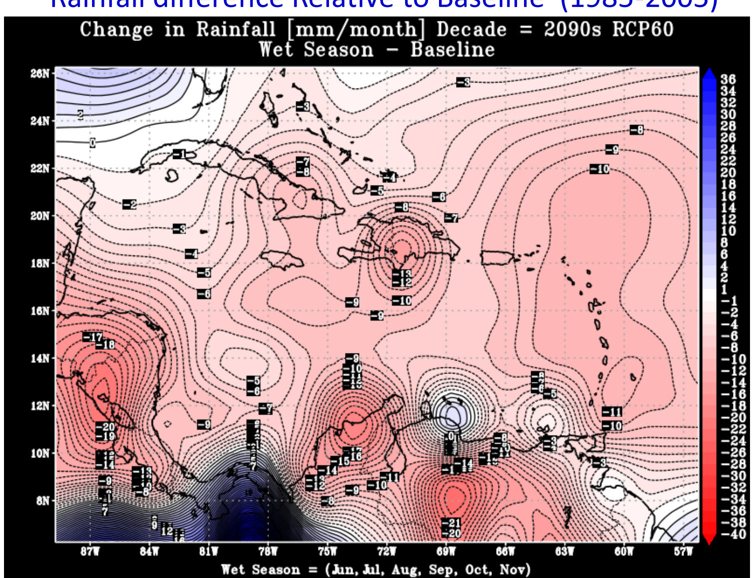
Rainfall difference Relative to Baseline (1985-2005)



Projected Wet Season Rainfall

RCP 6.0 CMIP5 Multi-Models

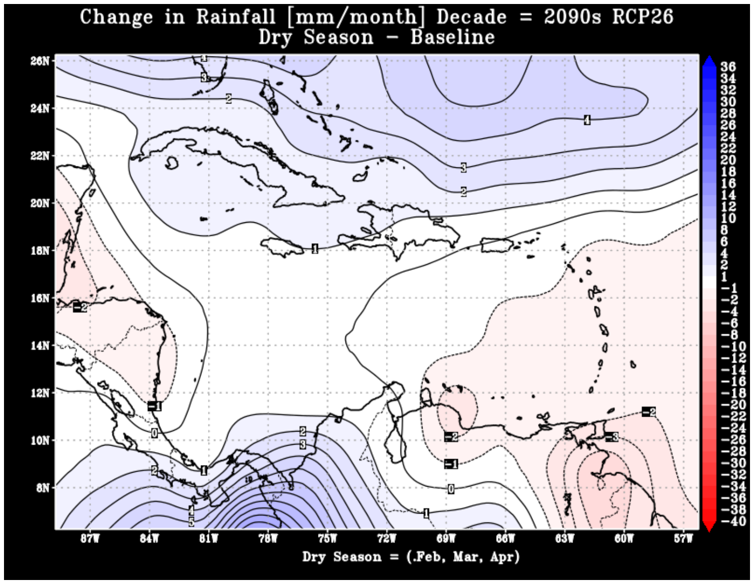
Rainfall difference Relative to Baseline (1985-2005)



Projected Dry Season Rainfall

RCP 2.6 CMIP5 Multi-Models

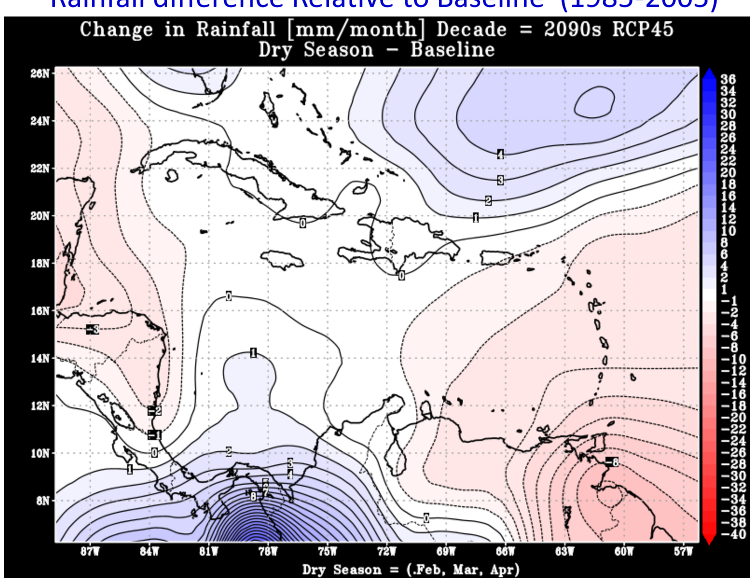
Rainfall difference Relative to Baseline (1985-2005)



Projected Dry Season Rainfall

RCP 4.5 CMIP5 Multi-Models

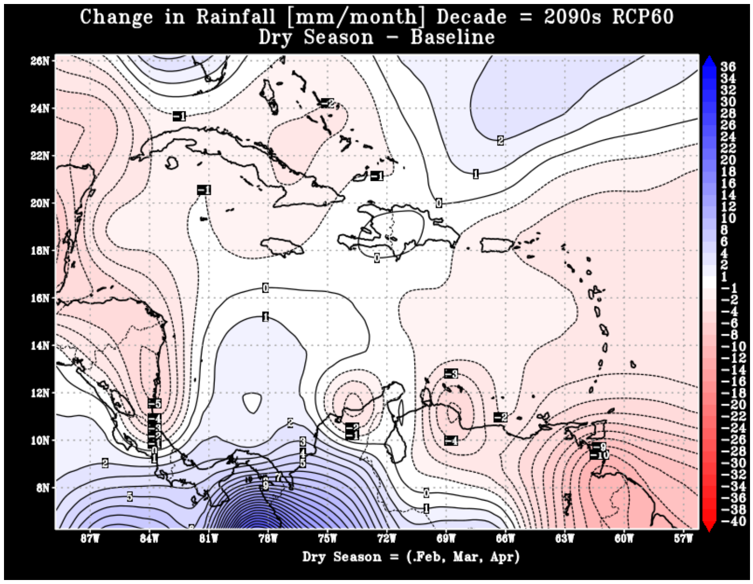
Rainfall difference Relative to Baseline (1985-2005)



Projected Dry Season Rainfall

RCP 6.0 CMIP5 Multi-Models

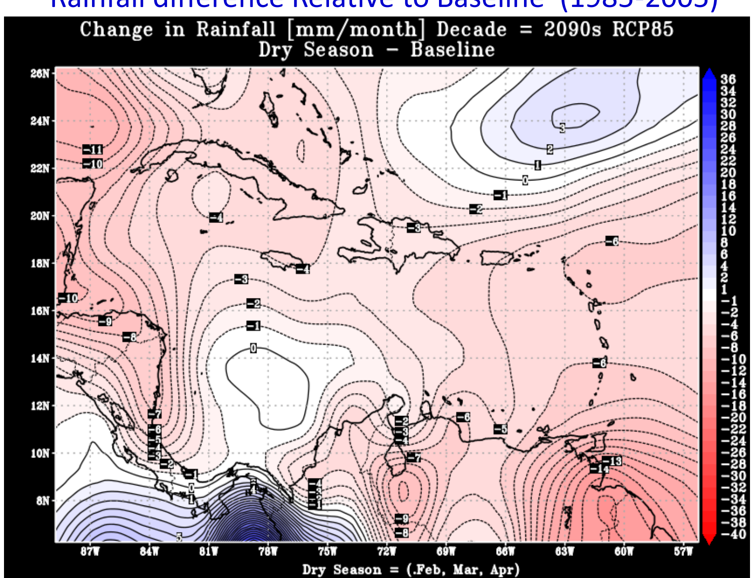
Rainfall difference Relative to Baseline (1985-2005)



Projected Dry Season Rainfall

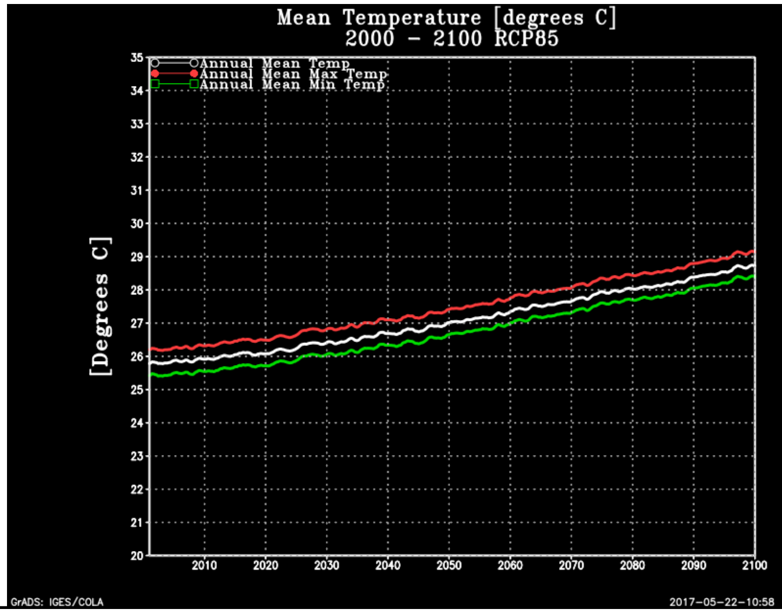
RCP 8.5 CMIP5 Multi-Models

Rainfall difference Relative to Baseline (1985-2005)



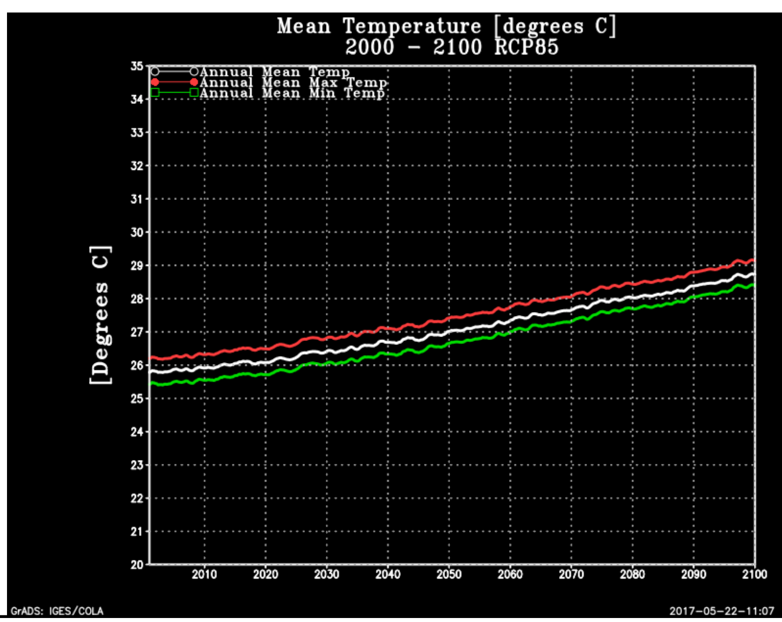
Projected Temperature - St. Lucia

RCP 2.6 - 8.5 CMIP5 Multi-Models

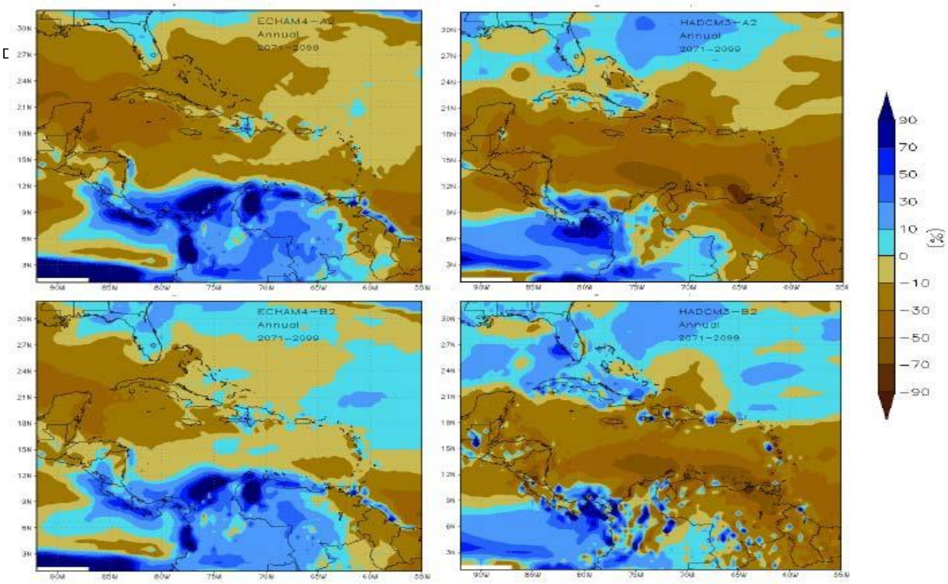


Projected Temperature – Kingston, Jamaica

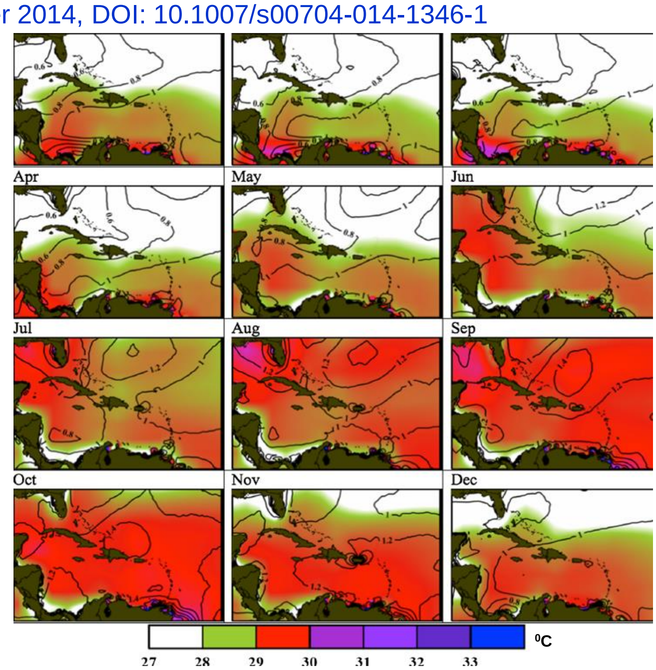
RCP 2.6 - 8.5 CMIP5 Multi-Models



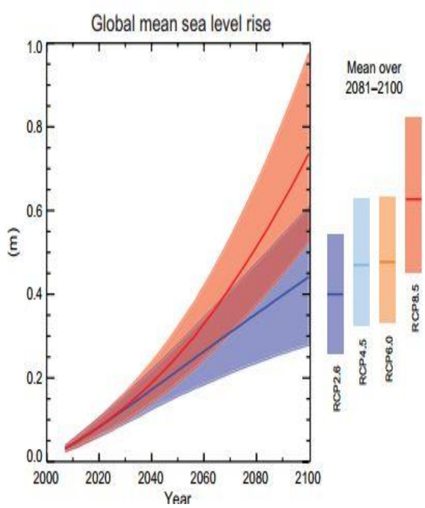
Drying trend between -25% and -30 % by end of Century. Drying far exceeds natural variability. Drier wet season likely (Taylor, 2011)



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

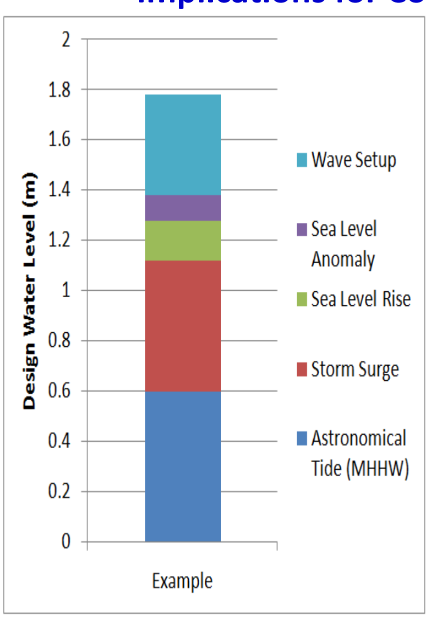


20^{th} Century Observed SLR in SIDS Regions



- 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

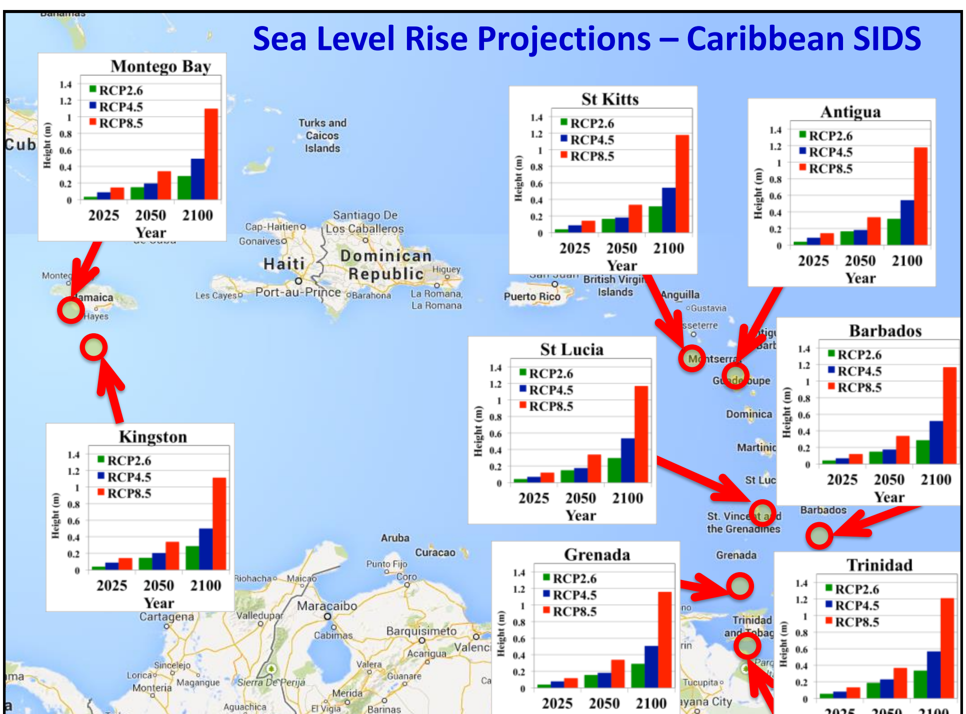
v Storm Surge

Note:

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

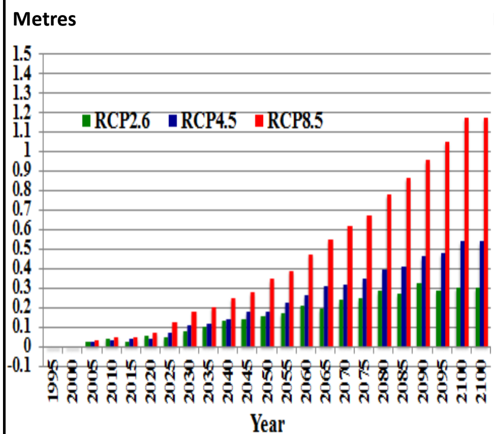
In coastal areas, quantitatively small changes have disproportionately large effects, e.g. storm surge

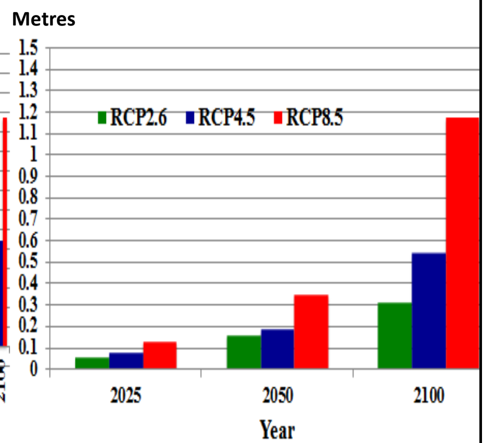
- Storm surge is associated with a rapid fall in barometric pressure, accompanied by strong *onshore* winds, as hurricane passes → '*Inverse barometer*' triggers a rapid elevation of H_2O level.
- Surge generates large surface waves, leading to the 'piling up' of H_2O at the coast.
- Relationship between 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:
Relative to 1985-2005 Baseline (CMIP5 Data Archive)

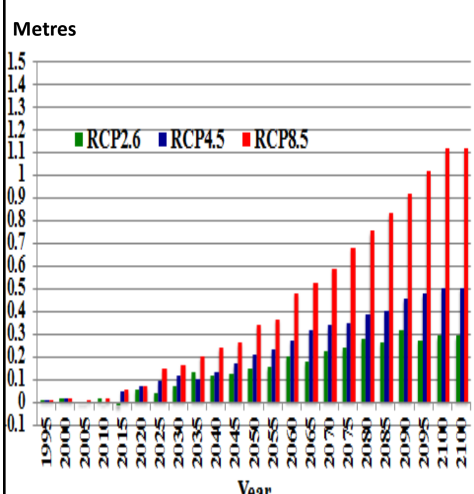
Data extracted for Grid Cells 13.5° N, 60.5°W (Hewanorra Airport) and Port Vieux Fort 14.5° N, 60.5° W (George F.L. Charles Airport & Port Castries)

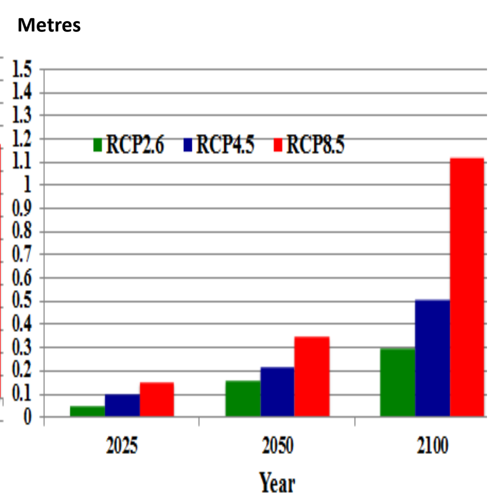




Kingston, Jamaica, Sea Level Rise Projections:
Relative to 1985-2005 Baseline (CMIP5 Data Archive)

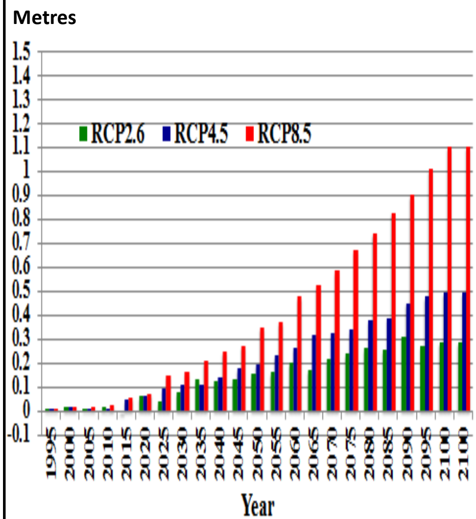
Data extracted for Grid Cell 17.5° N, 76.5°W
(Norman Manley Airport & Kingston Container Terminal)

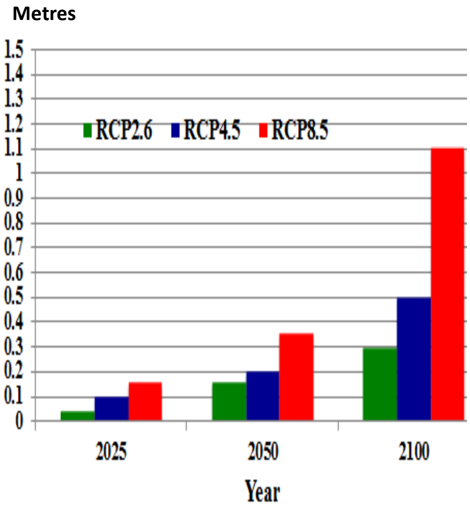




Montego Bay, Jamaica: Sea Level Rise Projections Relative to 1985-2005 Baseline (CMIP5 Data Archive)

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





Jevrejeva, S., L. P. Jackson, R. E. M. Rivac, A. Grinsted and J. C. Moore, 2016. 'Coastal Sea Level Rise with Warming Above 2 °C'. *Proceedings National Academy of Sciences* (PNAS) 113 (47), 13342–13347

"If warming continues above 2 °C, then, by 2100, sea level will be rising faster than at any time during human civilization, and 80% of the global coastline is expected to exceed the 95th percentile upper limit of 1.8 m for mean global ocean sea level rise. Coastal communities, notably rapidly expanding cities in the developing world, small island states, United Nations Educational, Scientific and Cultural Organization Cultural World Heritage sites, and vulnerable tropical coastal ecosystems will have a very limited time after midcentury to adapt to these rises".

Transport & Infrastructure Damage - Hurricane Lenny, Nov. 1999

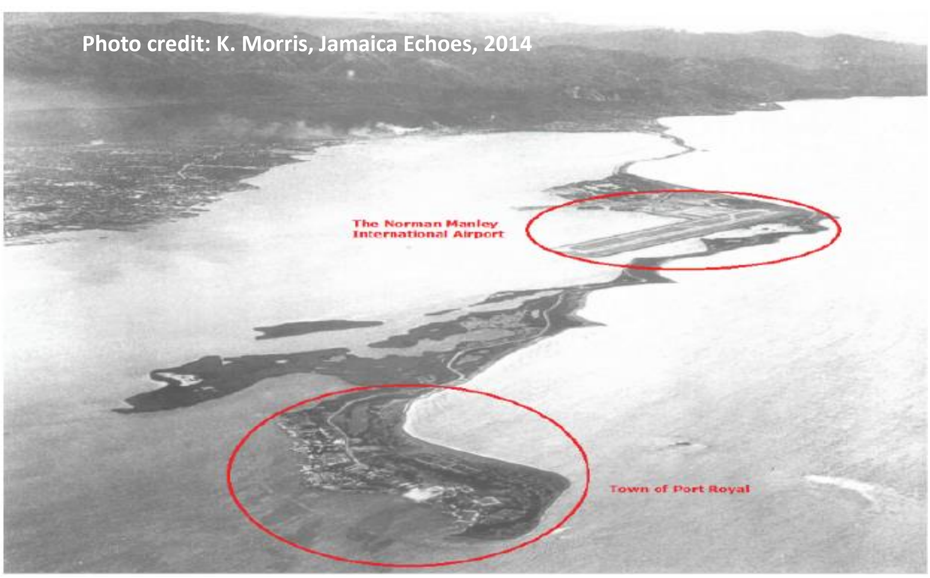
Northwestern & southern tip of the island most affected - landslides, severe beach erosion, airport flooded; 65% of Barbuda flooded, sanitary & water storage facilities overflowing; USD 51.3 M damages.

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.

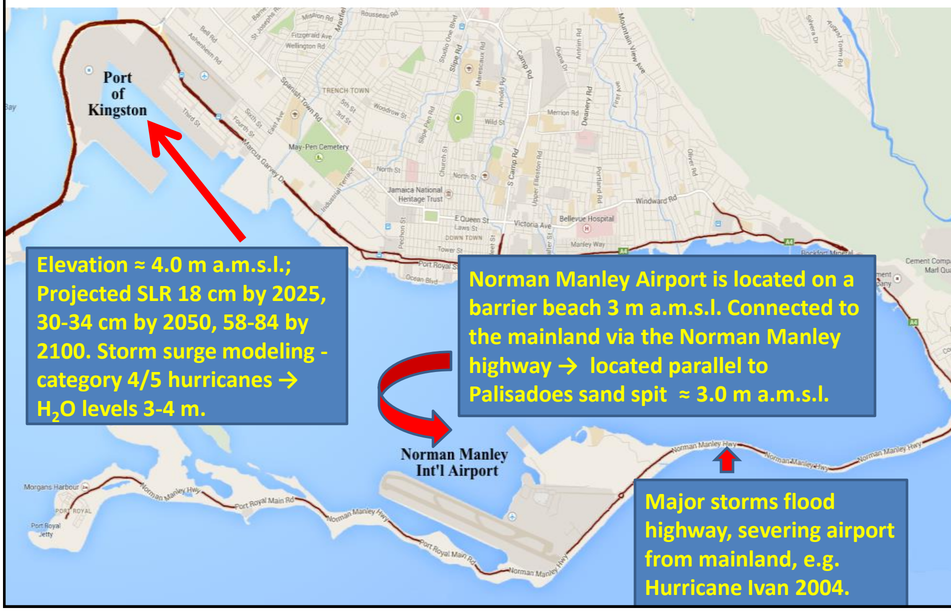
Most damage at Soufriere , waterfront, Gros Islet, Anse La Raye, Choiseul; severe erosion on NW coast, housing & tourism damage; damage to seaport, flooding at airports; hospital cut off from town; USD 6.6 M.

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.

Aerial Photo Showing Location of Norman Manley Airport and Town of Port Royal



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



Palisadoes Highway Protection - Main Access to Norman Manley Airport (Photo credits: K. Morris. *Jamaican Echoes*) 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:** • Lower air density • Reduced lift generated by aircraft wings; slower climbs • Effect on performance & efficiency	• Lower take-off weights/loads • Longer runways
More frequent Intense rainfall events	**Terminals, warehouses & related facilities**	• Greater incidence of flooding • Sewerage & drainage capacities exceeded, etc. • Disruptions and down-time • Business losses; possible loss of market share • Higher maintenance & operation costs	• Redesign/retrofitting of infrastructure (e.g. drainage, sewerage) for greater capacity & efficiency • Increased insurance/re-insurance to cover liabilities, demurrage, etc. • 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

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