Variability and Change in Tropical Cyclone Characteristics: Coupled Atmosphere-Ocean Drivers and Coastal Impacts

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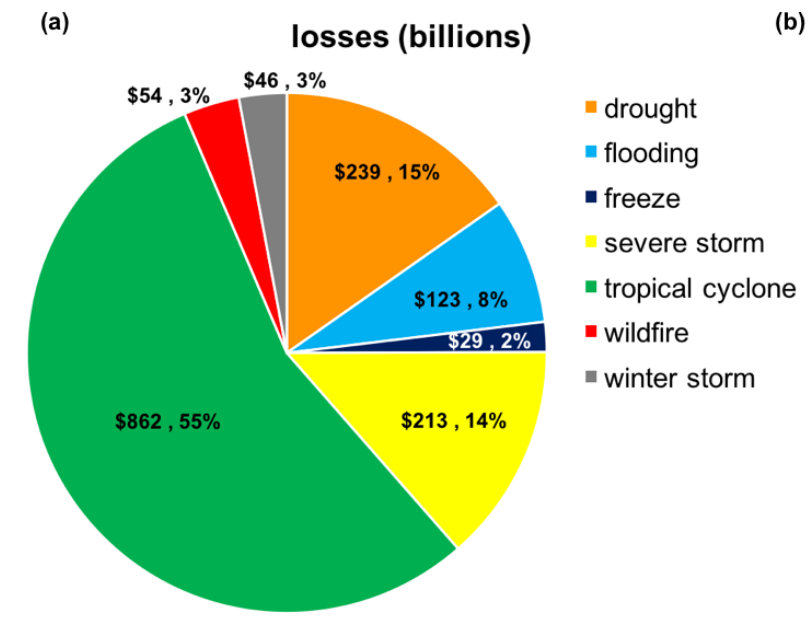
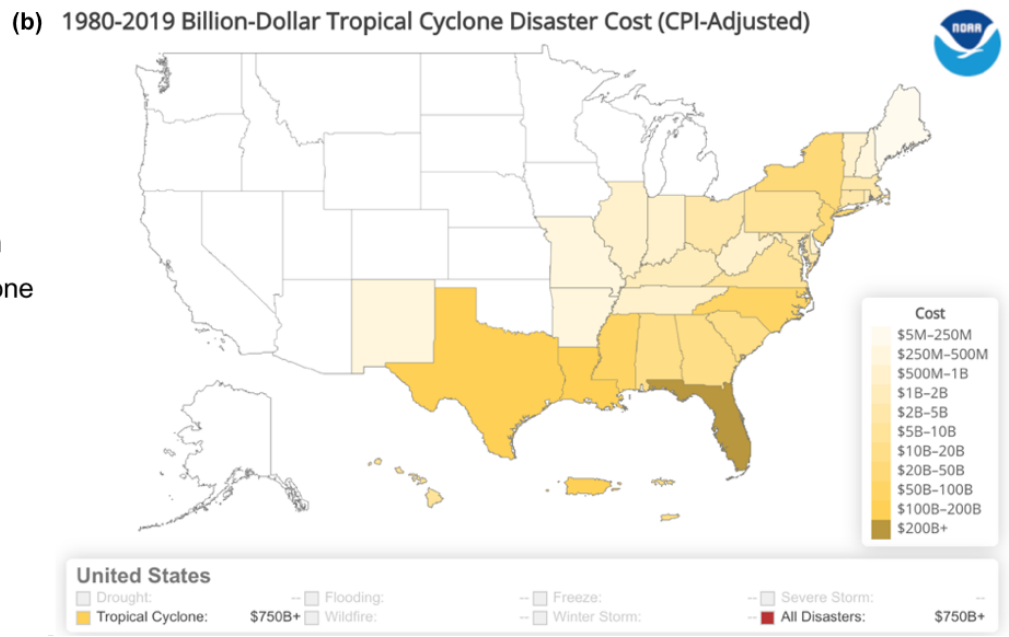
U.S. DEPARTMENT OF ENERGY
Office of Science

Grand challenges

- projecting future change in tropical cyclone (TC) number regionally and globally
- simulating and predicting TC intensity, including rapid intensification
- understanding coastal impacts due to co-occurring extremes





Tropical cyclones account for >50% of economic losses from natural disasters.

Project objectives

Local coupled TC-ocean processes

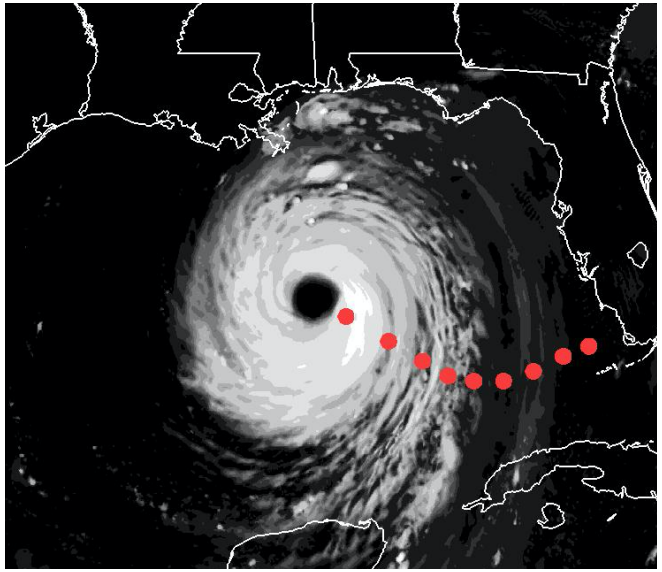
Quantify how atmosphere-ocean interactions shape tropical cyclone (TC) intensity in a changing climate, using a convection-permitting regional atmosphere-ocean model.

Large-scale TC drivers

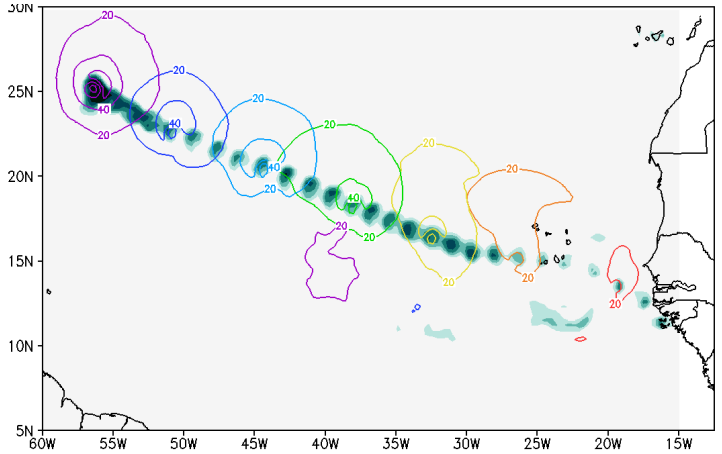
Understand how large-scale drivers and TC precursors control global TC frequency, landfall, and track, using high-resolution E3SM simulations.

Coastal impacts

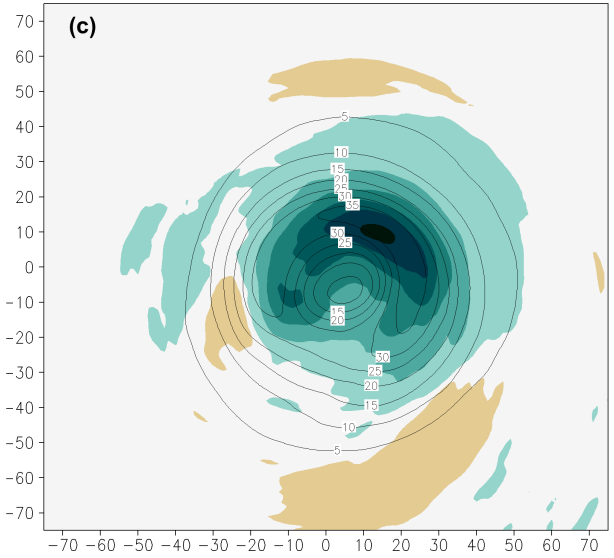
Project coastal impacts from TCs and sea-level rise due to storm surge, precipitation, and wind, using results from (1) and (2) and a storm surge model.



3km resolution tropical cyclone simulation



A simulated tropical cyclone forms from an African Easterly wave



Projected tropical cyclone rainfall change

Objective 1: Local coupled TC-ocean processes

How do physical processes in the atmosphere and ocean lead to constructive or competing TC-ocean feedbacks in a changing climate, and how do they influence TC intensity, intensification rate, and precipitation?

Peak 10-m wind speed (kt)

TC	resolution	hist.-preind.	RCP4.5-hist.	RCP6.0-hist.	RCP8.5-hist.
Katrina	27 km (P)	-1.0			11.0 **
	9 km (P)	2.0			15.2 **
	9 km	-0.5			13.5 **
	3 km	-2.4			13.7 **
	4.5 km		6.0 **	8.5 **	13.8 **
Irma		-1.9	7.3 **	10.4 **	12.4 **
Maria		-1.5	7.5 **	10.9 **	12.9 **
Andrew			-3.3	-2.4	-1.7
Bob			-6.1 **	-2.4 *	2.1
Floyd			11.2 **	13.5 **	
Gilbert			18.0 **	18.6 **	28.8 **
Ike			12.8 **	14.1 **	18.0 **
Matthew			10.6 **	11.1 **	15.8 **
Iniki			-0.4	-3.9	4.6 *
Haiyan			6.7 **	3.8	12.3 **
Morakot			0.5		
Songda			10.4 **	5.5 **	
Yasi			11.2 **	13.7 **	18.9 **
Gafilo			8.6 **	8.8 **	16.8 **

-25 -15 -5 0 5 15 25 kt

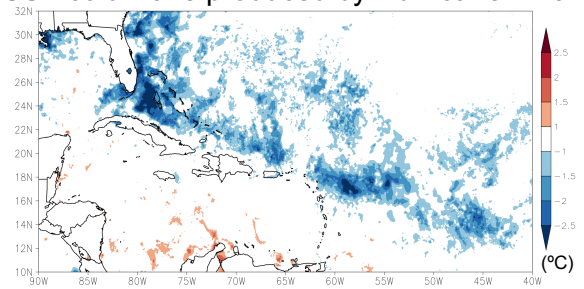
% change in rainfall

TC	resolution	hist.-preind. preind.	RCP4.5-hist. hist.	RCP6.0-hist. hist.	RCP8.5-hist. hist.
Katrina	27 km (P)	4.7 **			13.0 **
	9 km (P)	4.5 *			12.7 **
	9 km	5.0 *			13.5 **
	3 km	8.7 **			14.4 **
	4.5 km		7.1 **	14.6 **	16.5 **
Irma		4.2	4.5	8.8 **	2.1
Irma ^		6.3 *	17.5 **	26.1 **	27.8 **
Maria		4.4	7.0 *	7.2 *	7.7 *
Maria ^		8.9 **	21.8 **	23.4 **	36.9 **
Andrew			0.3	5.1	4.8
Bob			6.5 **	11.9 **	13.5 **
Floyd			12.3 **	13.5 **	
Gilbert			13.5 **	16.5 **	25.3 **
Ike			15.0 **	20.2 **	26.5 **
Matthew			2.0	1.1	4.0
Iniki			5.8 *	4.9	15.2 **
Haiyan			9.5 **	12.8 **	31.3 **
Morakot			6.8 *		
Songda			19.5 **	10.6 **	
Yasi			15.6 **	23.1 **	35.2 **
Gafilo			19.7 **	16.8 **	41.6 **

-25 -15 -5 0 5 15 25 %

Robust future increase in intensity and rainfall of major TCs globally, in atmosphere-only convection-permitting simulations.
Patricola and Wehner (2018) *Nature*

SST cold wake produced by Hurricane Irma



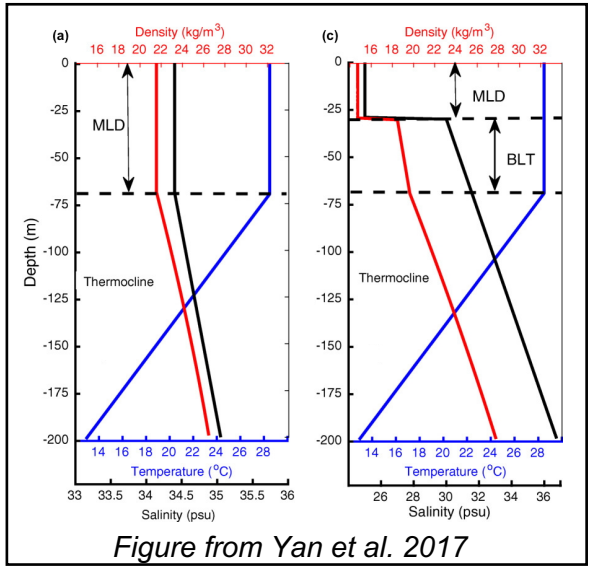


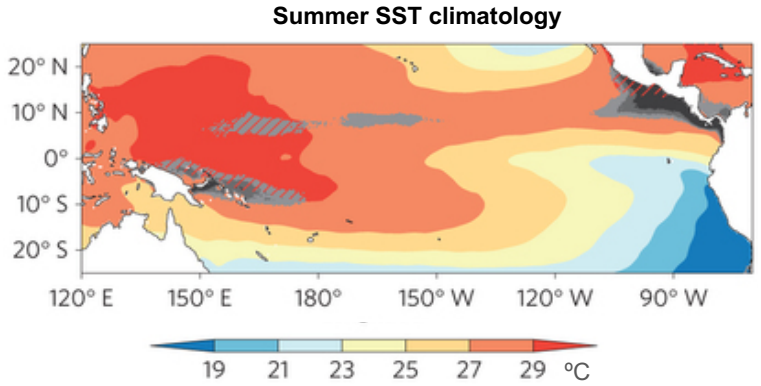
Figure from Yan et al. 2017

- changing TC intensity and wind-driven ocean mixing
- changing TC precipitation and freshwater flux to the ocean
- changes in upper-ocean thermal and salinity profiles (Balaguru et al.; Lin et al.)

Objective 2: Large-scale tropical cyclone drivers

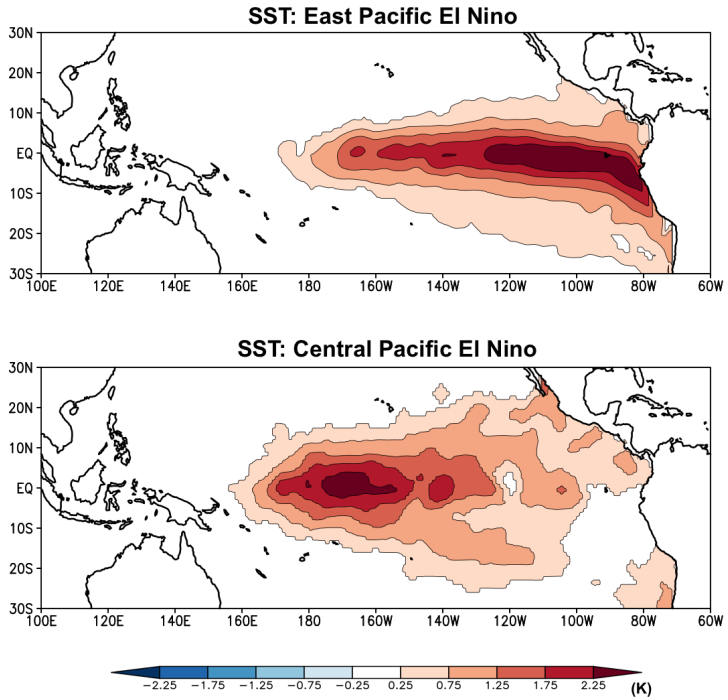
How do joint changes in intra-basin and inter-basin SST gradients and greenhouse gas and aerosol forcings influence the spatial and temporal statistics of landfalling TCs, and through what mechanisms?

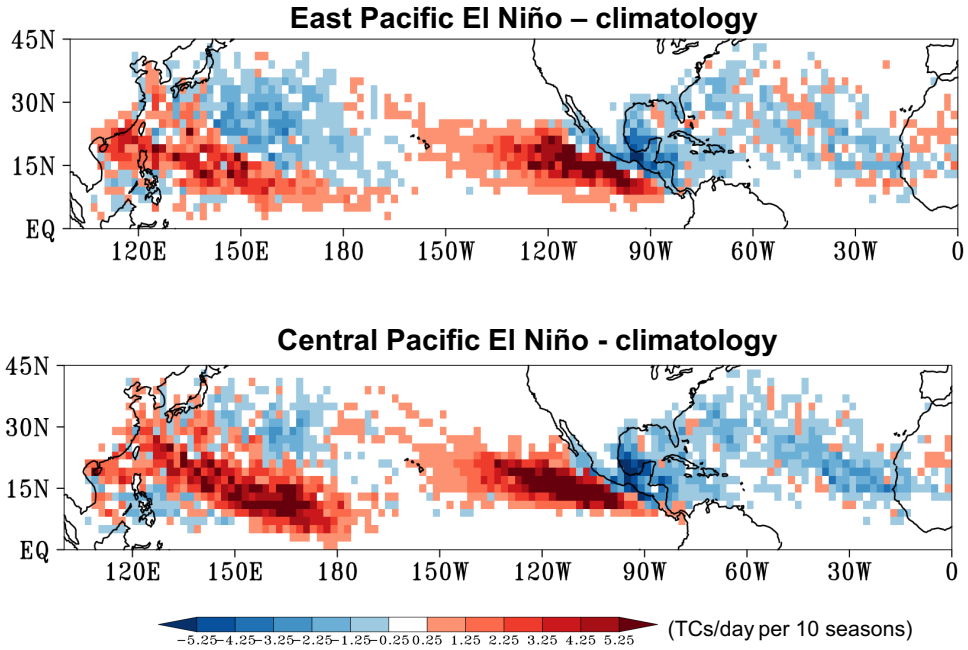
- Global and basin-wide TC frequency, landfall, track, and translation speed



Central Pacific SST warming more effectively suppresses Atlantic TC activity, because the warm pool is closer to the convective threshold than cold tongue.

Patricola et al. (2016) *Nature Geoscience*
Patricola et al. (2018) *J. Clim.*

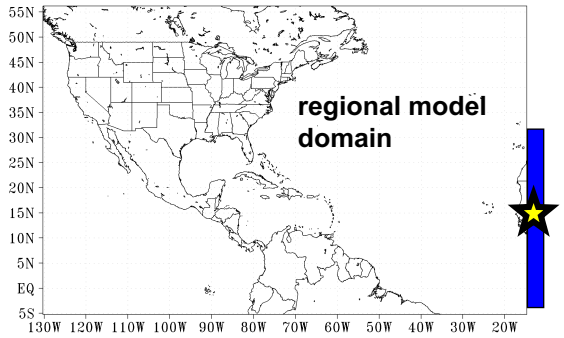


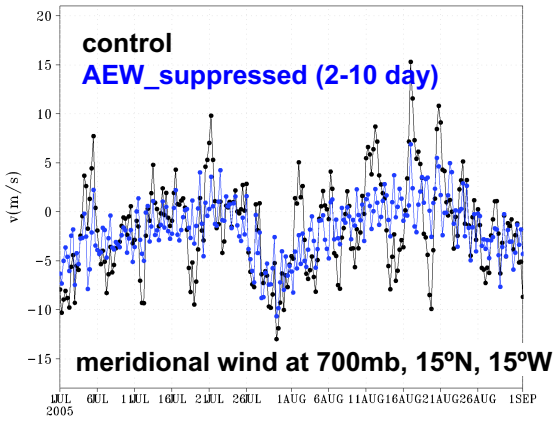


Objective 2: Large-scale tropical cyclone drivers

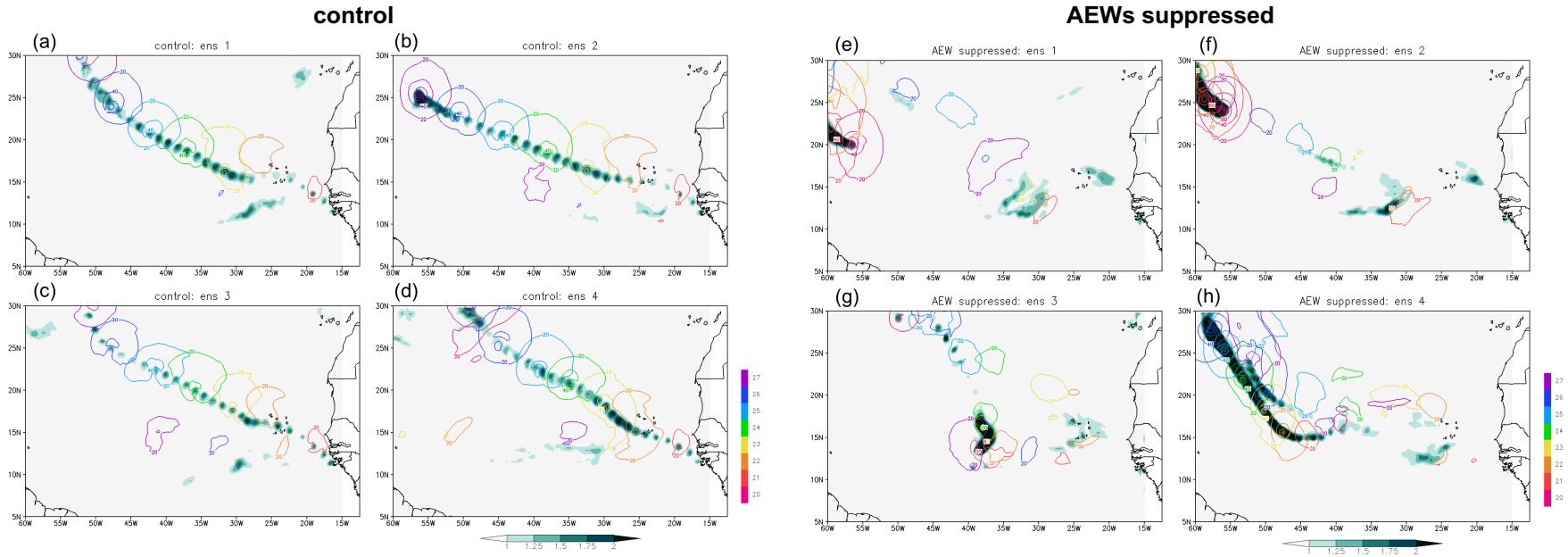
What factors limit TC genesis in the historical and future climate?

- Changes in characteristics of TC precursors and potential implications for changes in TC tracks
  - Future changes in AEWs: lightning talk by Emily Bercos-Hickey in Multi-year breakout





- Atlantic TCs are not limited by their typical precursor on season-climate timescales, in mechanistic regional climate model experiments.
- AEW activity is an unreliable predictor of variability/change in Atlantic TC number.

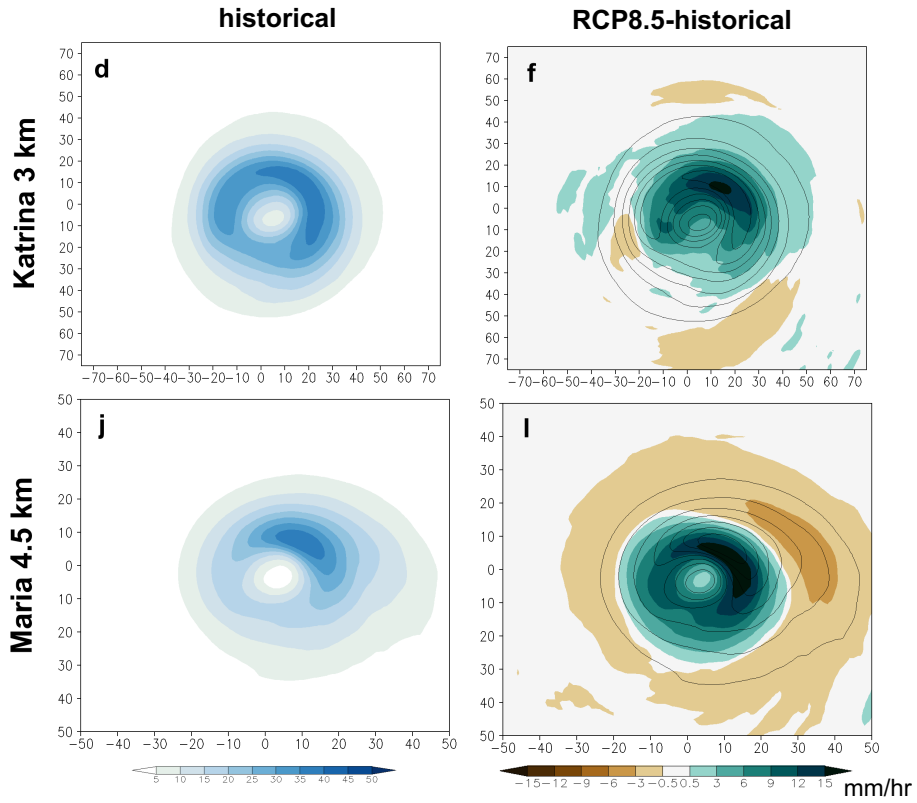


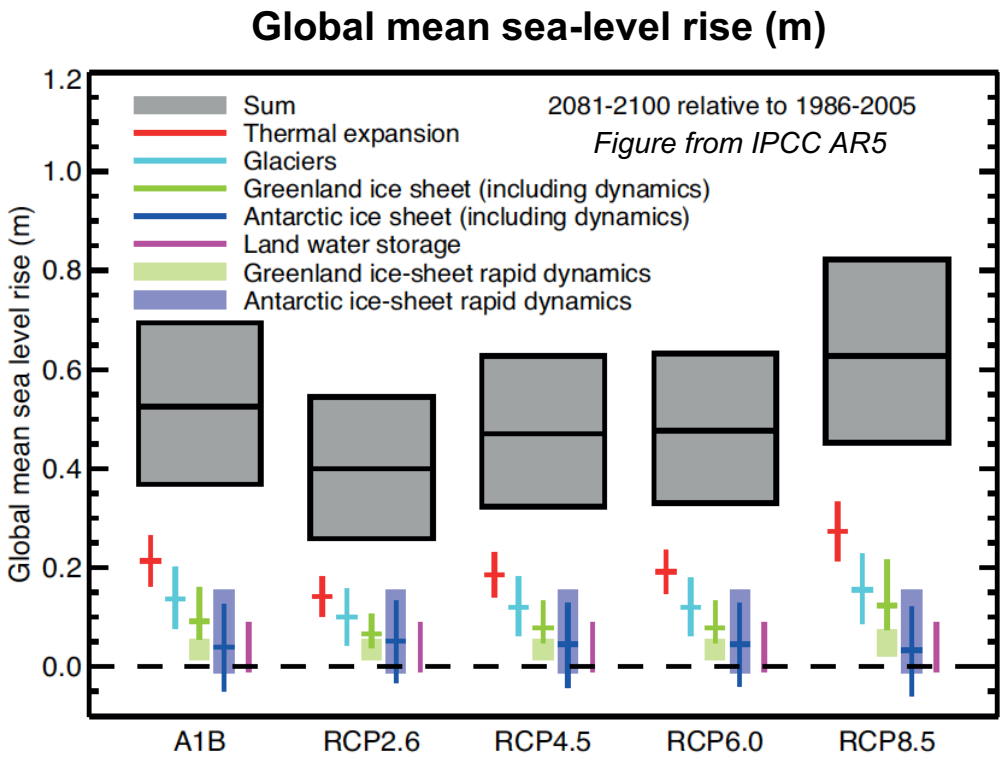
Patricola et al. (2018) *Geophysical Research Letters*

Objective 3: Coastal impacts

How are the changing characteristics of TCs, combined with projected sea-level rise, expected to impact the storm surge associated with TCs in a future climate?

- Joint changes in precipitation, wind, and storm surge extremes





Patricola and Wehner (2018) *Nature*

Summary

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Quantify how atmosphere-ocean interactions shape tropical cyclone (TC) intensity in a changing climate, using a convection-permitting regional atmosphere-ocean model.	Understand how large-scale drivers and TC precursors control global TC frequency, landfall, and track, using high-resolution E3SM simulations.	Project coastal impacts from TCs and sea-level rise due to storm surge, precipitation, and wind, using results from (1) and (2) and a storm surge model.

Thank you!

I am looking for graduate students and a postdoc to join my group.
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