Investigating the impact of a major hurricane on larval exchanges and disease propagation in Florida

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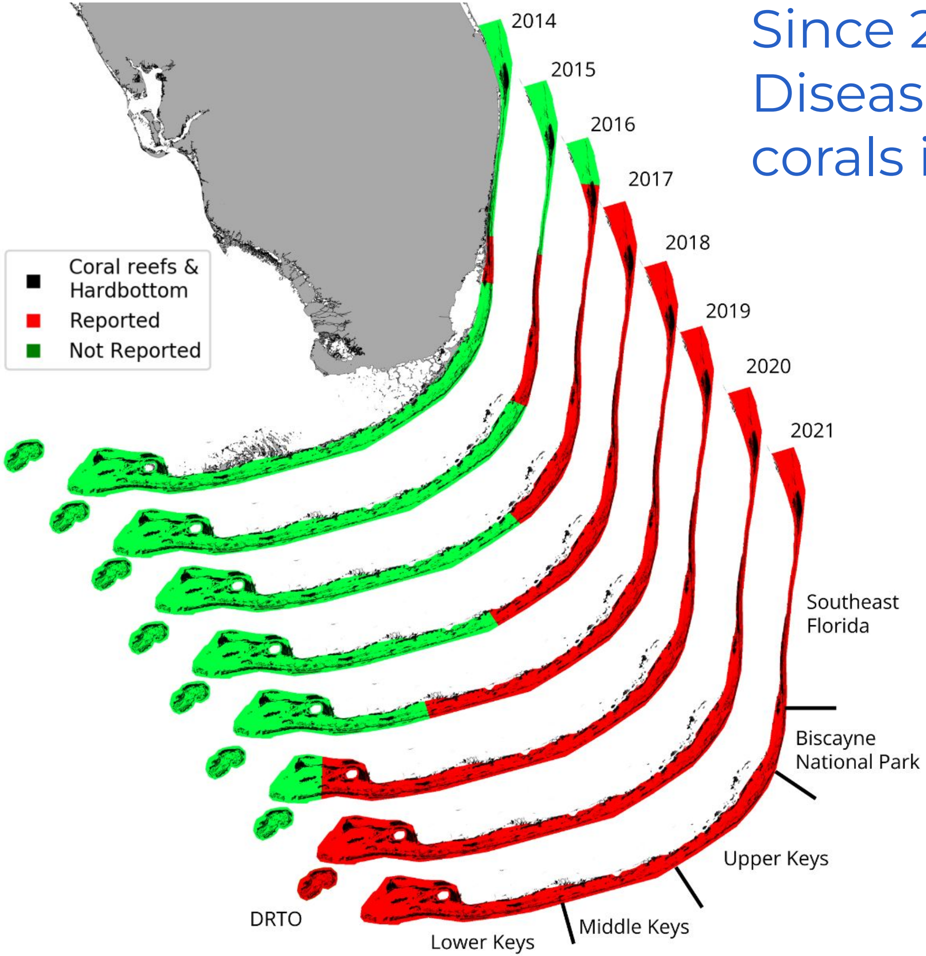
Since 2014, Stony Coral Tissue Loss Disease (SCTLD) has been decimating corals in Florida and the Caribbean



Worst coral disease outbreak **on record**

- At least 22 reef building species affected
- Decline in living coral tissue area of ~60% on impacted reefs.
- Up to a 95% decrease in density of susceptible species on affected reefs

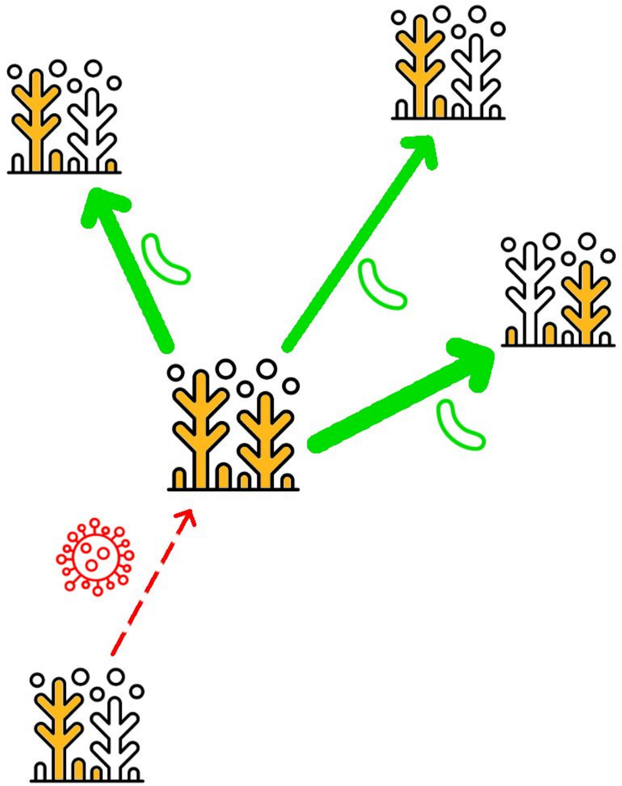
Evidence of **waterborne** disease transmission

As there is evidence of waterborne disease transmission, we studied its propagation by simulating reef **connectivity**

Larval exchanges between reefs promote the **resilience** of the network

However, these exchange processes can also cause the propagation of **disease agents**

Connectivity is thus a **double-edge sword**



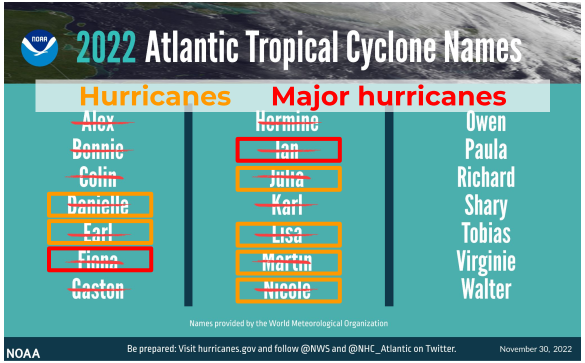
Major hurricanes will become more intense with climate change

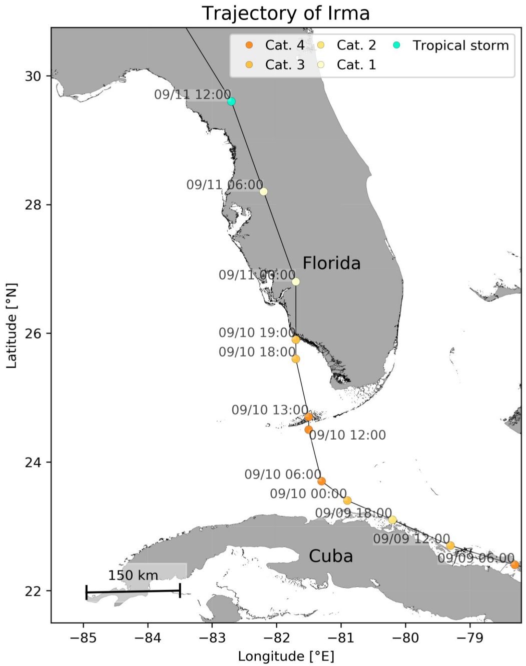
Florida is a prime **landfall target** for hurricanes.

Before Ian in 2022, Florida was hit by Cat. 4 hurricane **Irma** in 2017 .

Storm **waves interact** nonlinearly with **currents** and significantly **alter ocean circulation.**

Question: How do hurricanes impact larval and disease connectivity ?

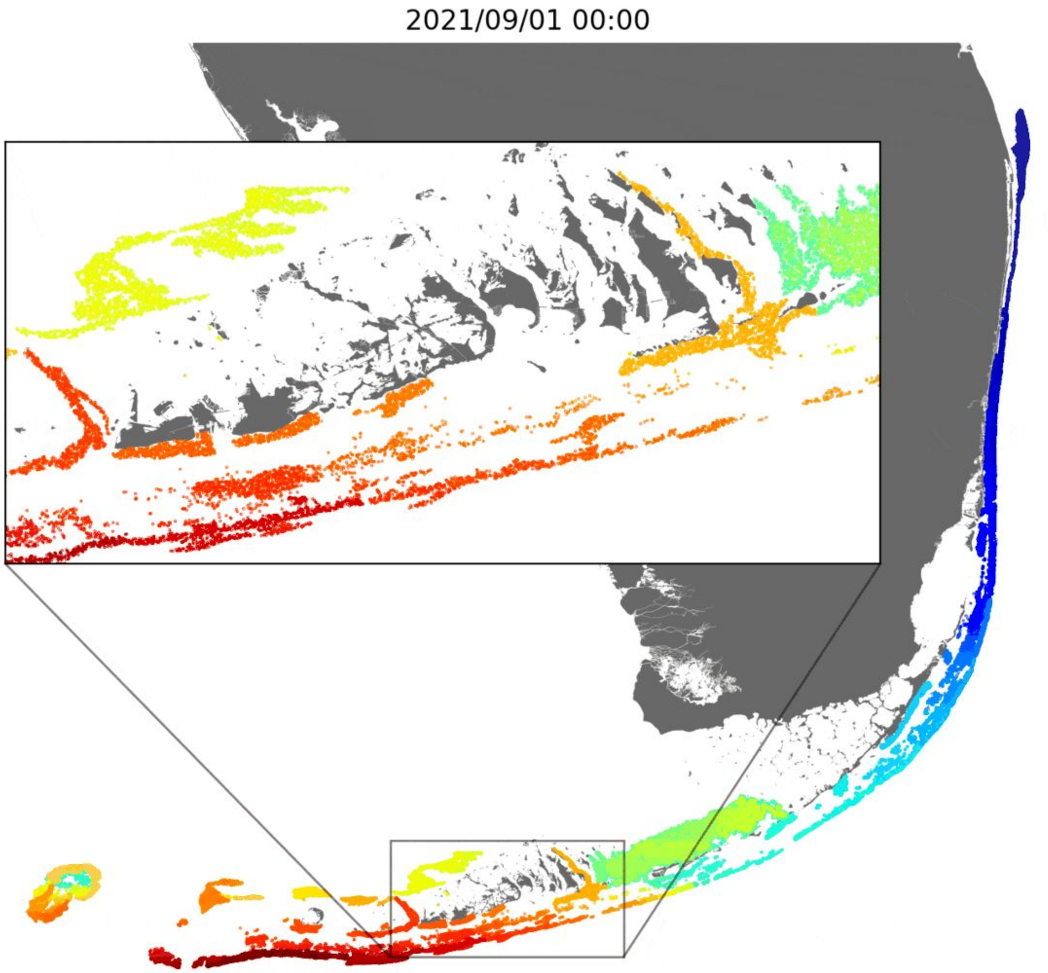




We modeled the transport of coral larvae and disease agents using a biophysical models

Virtual particles with a **biological state** are released over all reefs

The exchanges of particles between reefs are recorded in **connectivity matrices**



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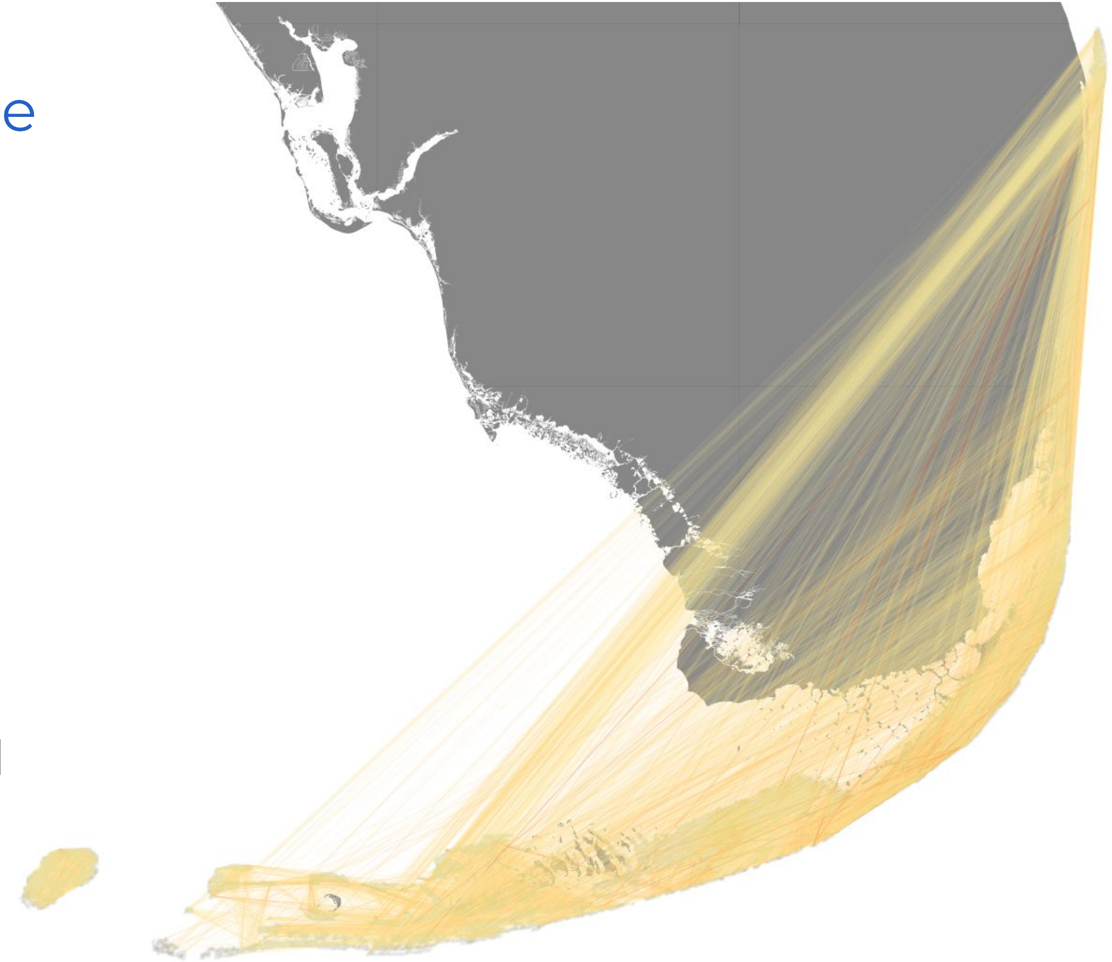
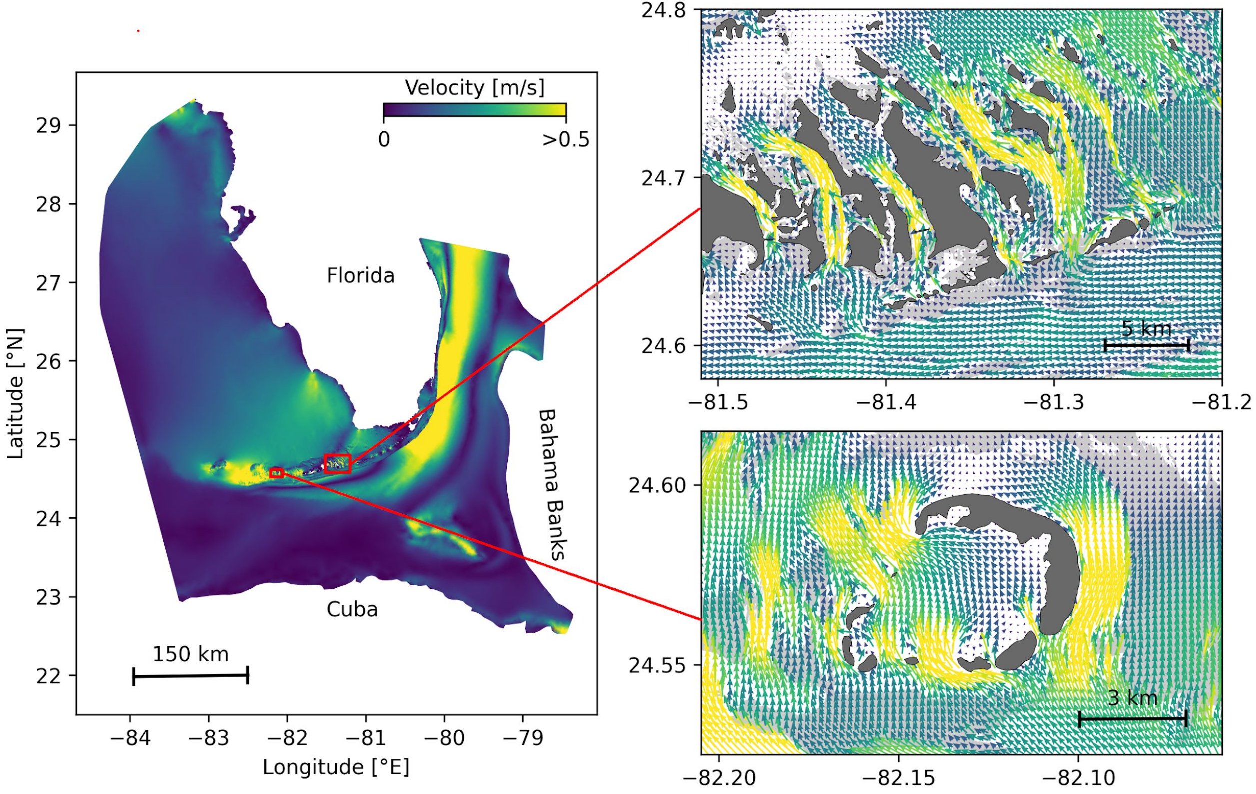


We simulated the ocean circulation at the reef scale with the coastal ocean model SLIM

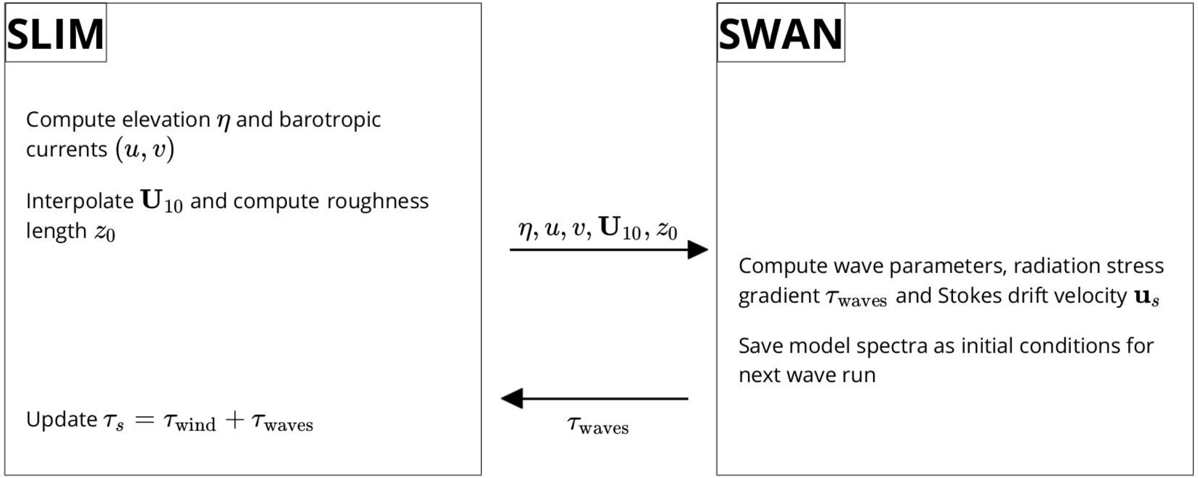
SLIM simulates the circulation around reefs and islands with a resolution of 100m (~10x more than existing models)



We coupled SLIM with the wave model SWAN to capture wave-current interactions during Irma

SLIM+SWAN has already been **successfully applied** and **validated** to study wave-induced transport processes **during Irma**[1]

We advected virtual **larvae** and **pathogens** using the simulated **currents** and **Stokes drift**



[1]Dobbelaere, T., Curcic, M., Le Hénaff, M., & Hanert, E. (2022). Impacts of Hurricane Irma (2017) on wave-induced ocean transport processes. Ocean Modelling, 171, 101947.

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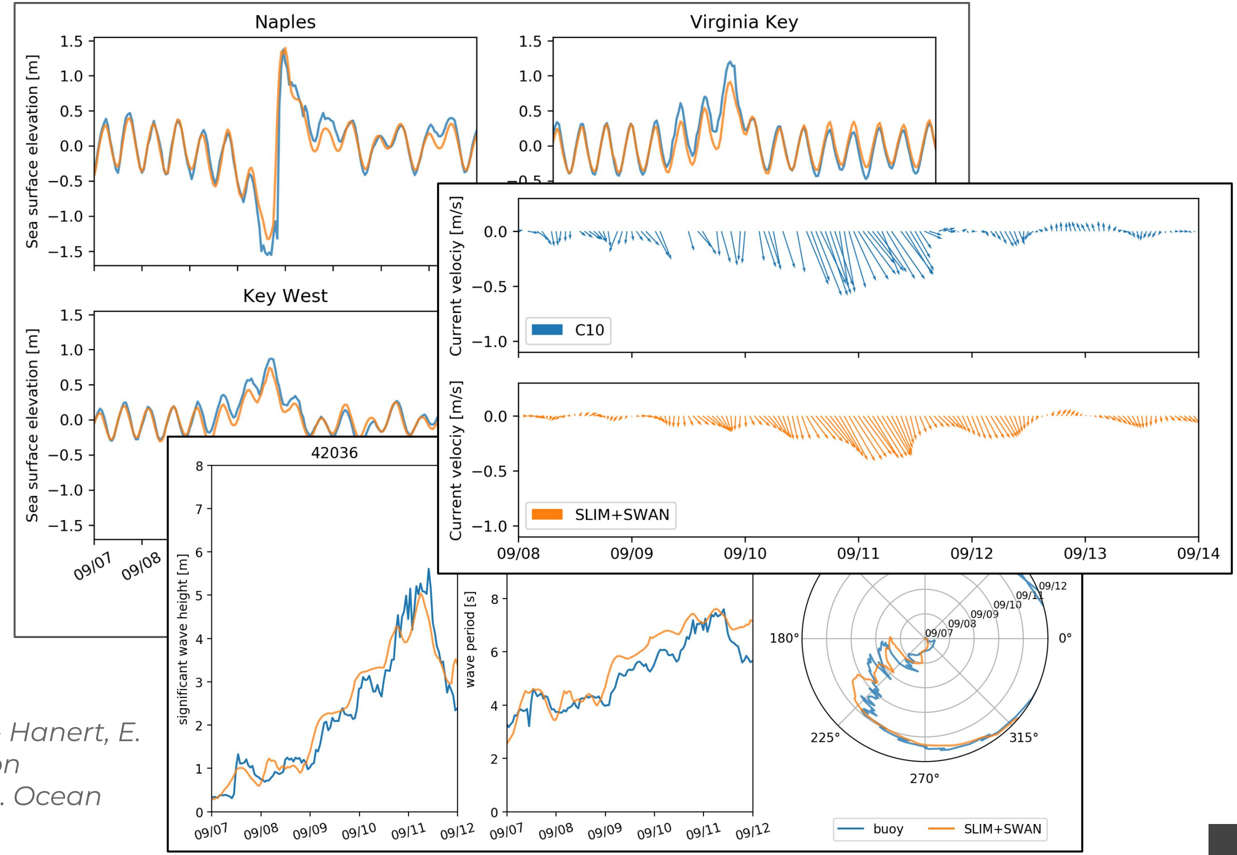

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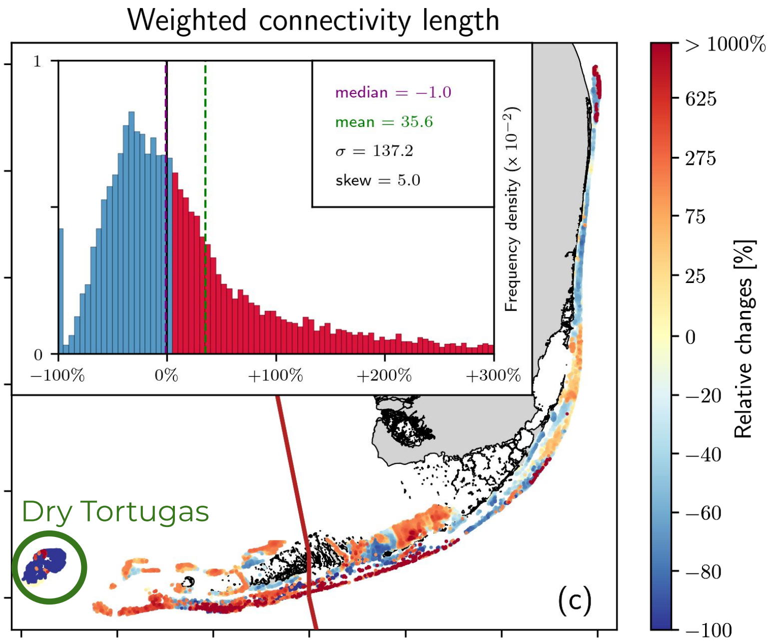
We compared different connectivity networks to evaluate the impact of Irma on larval and disease propagation

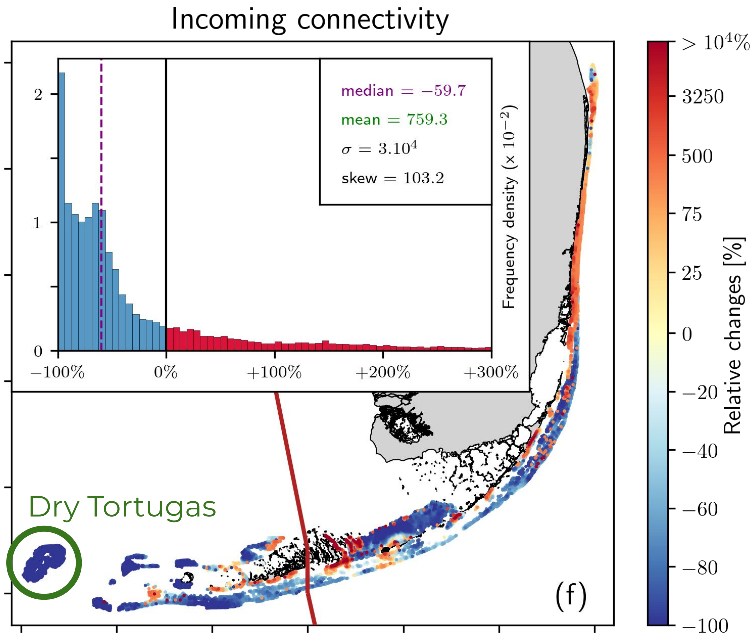
Irma made **landfall** in the Florida Keys on **Sep 10th, 2017**

Coral larvae	Disease agents
We simulated the 2017 **mass spawning** events of **Montastrea cavernosa** (10-12 Sep) Particles released on the **10th and the 11th** were **impacted by Irma**	Particle **release started** on the **5th** to account for the impact of Irma on pathogens already present in the water column.

In **both cases**, particles released on the **12th** were used as **reference** and particle trajectories were simulated during **3 months after** their **release**

For coral larvae, Irma caused an increase in weighted connectivity length but decreased incoming connectivity

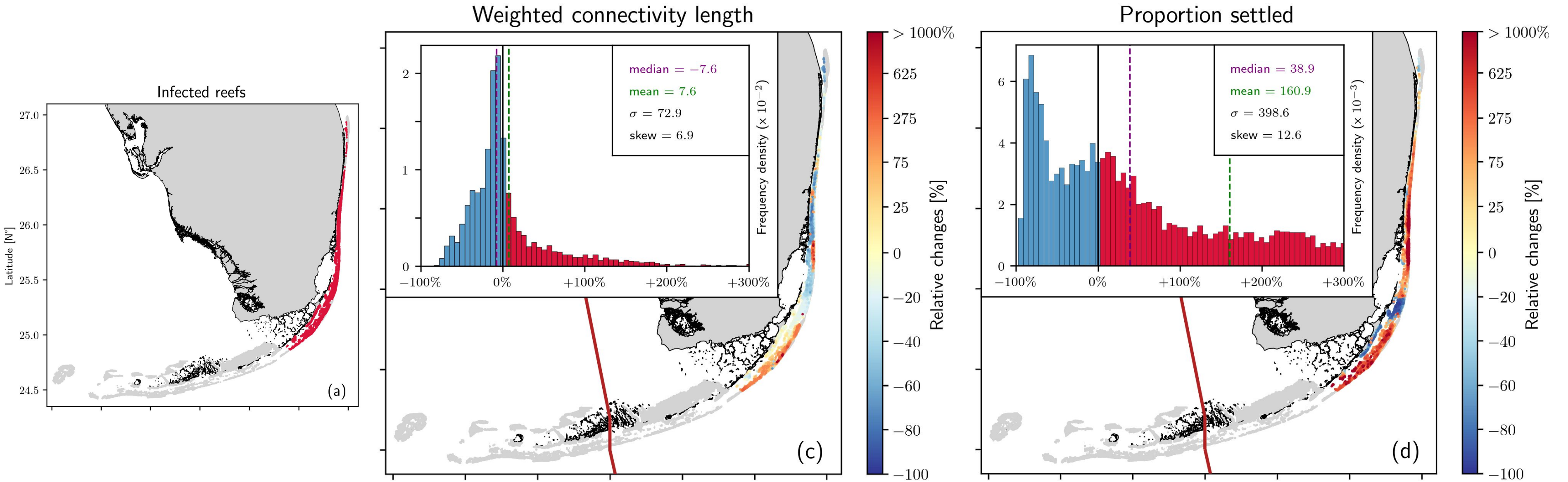




By accelerating currents, Irma locally strengthened and multiplied **longer connections**...

... However, it **fragmented communities** and **isolated** regions such as the Dry Tortugas

Irma likely acted as a superspreader event for the SCTLD



Under the effect of the hurricane, agents released from the disease front reached reefs located **further away** and were **more likely to settle**

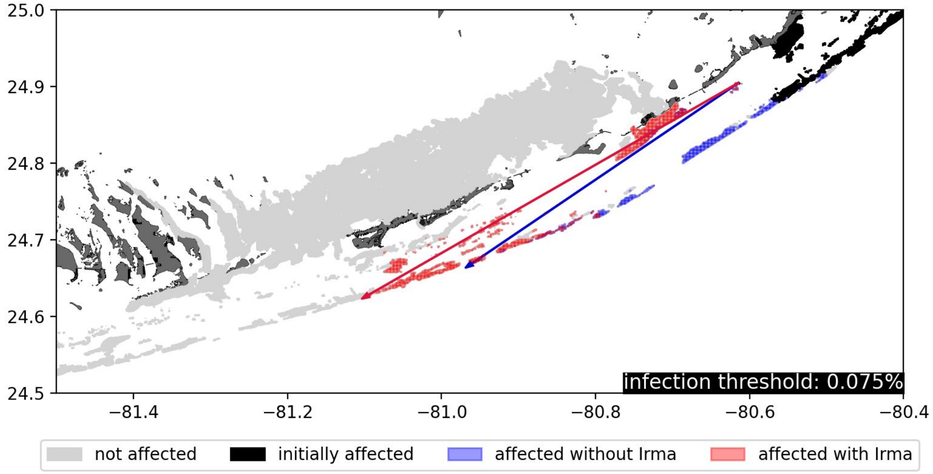
Epidemiological modeling suggests that Irma might have accelerated the propagation of the disease by up to 50%

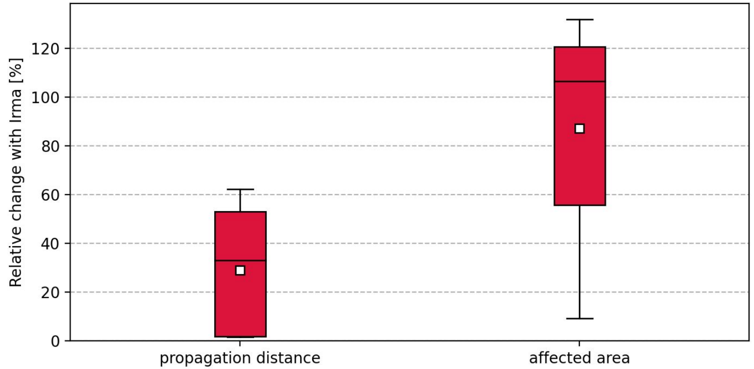
The **connectivity matrices** were given as input for the **coupled epidemiological model** of Dobbelaere et al. (2020)[2]

This model was run with different **infection threshold** values consistent with the observed spread of the disease

On average , the impact of **Irma** is equivalent to **25 days** of disease **propagation**

[2]*Dobbelaere, T., Muller, E. M., Gramer, L. J., Holstein, D. M., & Hanert, E. (2020). Coupled epidemio-hydrodynamic modeling to understand the spread of a deadly coral disease in Florida. Frontiers in Marine Science, 7, 591881.*





In brief

Our results suggest that Irma **locally strengthened** and **multiplied** larval exchanges over **long distances** in the Lower and Upper Keys to the **detriment** of the **other areas** of Florida's Coral Reef

Low reef density areas and **isolated** reefs such as the Dry Tortugas seem to be the **most likely** to be **endangered** by hurricanes while regions with a **high density** of reefs **might benefit** from hurricane-induced transport.

Irma likely acted as a **superspreader** event for the propagation of SCTLD in Florida