Unveiling a coral disease dynamics: SCTLD's propagation into the US Virgin Islands reefs

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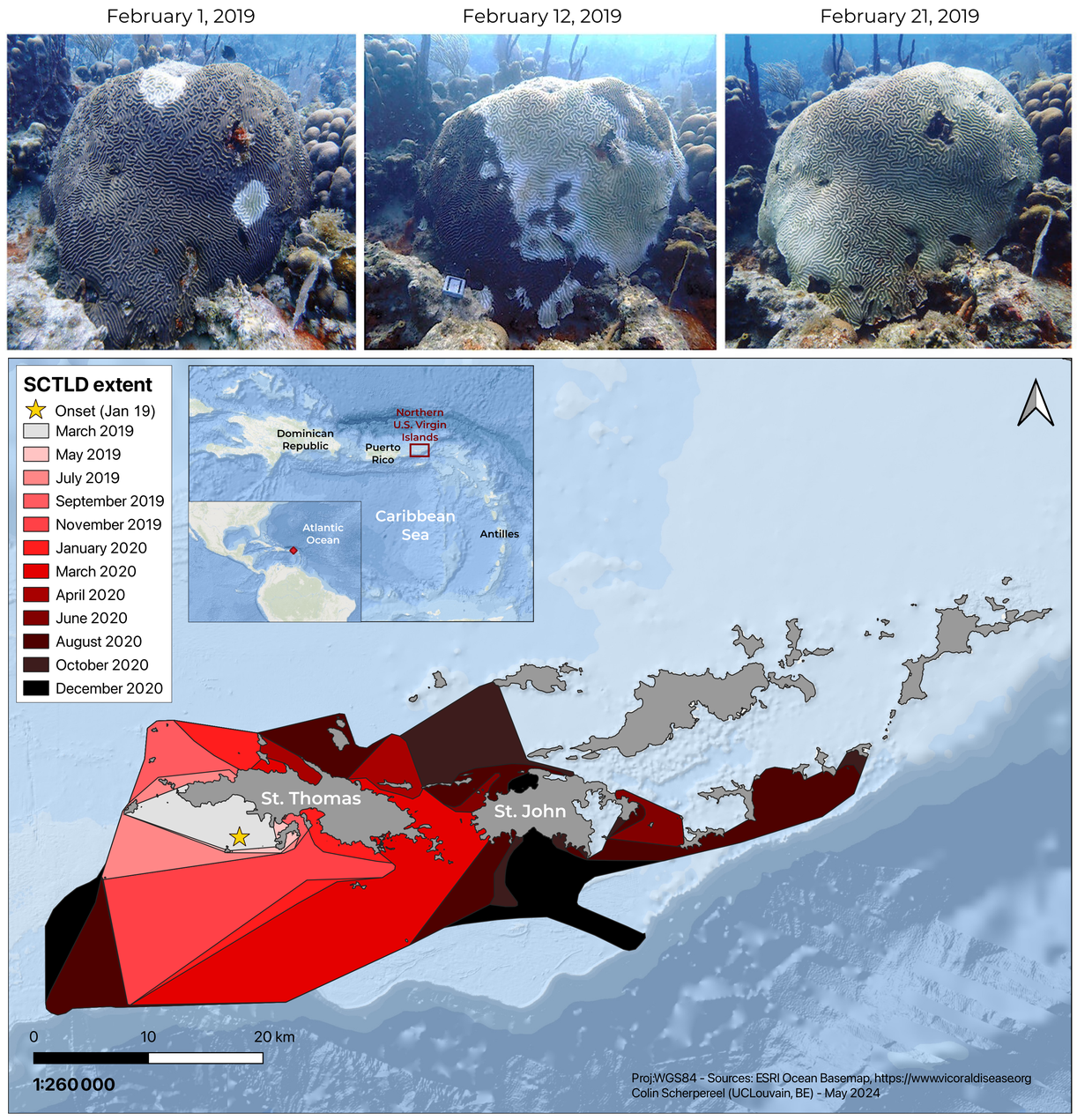
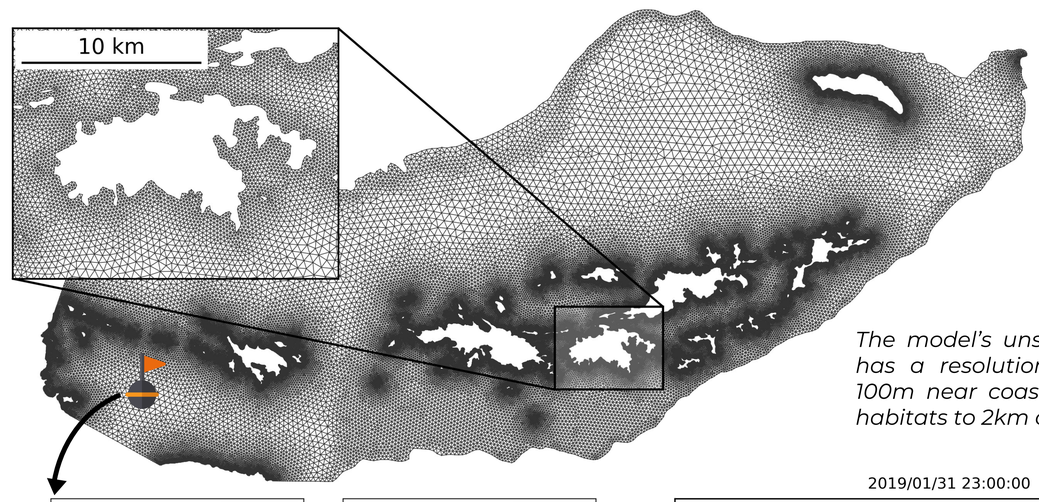
Worst outbreak on record: the **S**tony **C**oral **T**issue **L**oss **D**isease

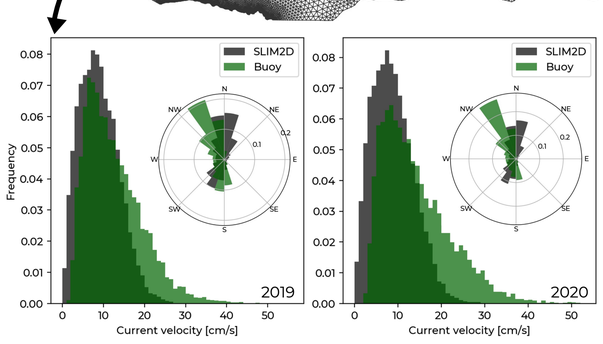
Over the past 10 years, the SCTLD has spread through the Caribbean and the Gulf of Mexico, leading to **significant losses in coral cover** (30-60% in affected regions) **and diversity**.
The SCTLD affects at least **23 species** of scleractinian corals with a large range of susceptibility and **can lead to the death of a colony within a few days**. Even though its etiology has not been clearly identified yet, transmission is likely to operate through **direct contact or via mobile vectors**, such as fine sediments, coral mucus, or dead tissues.
The **community structure** of many marine species is also greatly impacted by the resulting local coral extinctions.

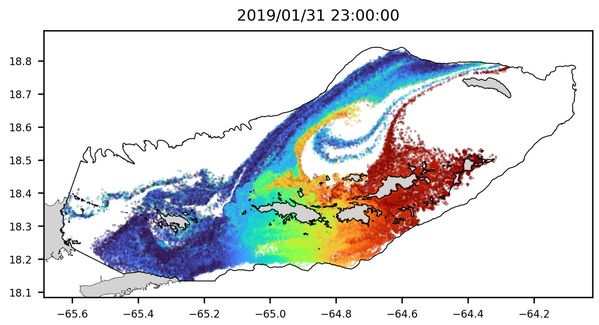
Since 2019, the SCTLD has become the greatest threat to coral reefs in the **U.S. Virgin Islands**, above climate change and anthropogenic pressure.
The disease has spread from **North-West to South-East** in the islands, consistently with the pattern observed in the broader Caribbean basin.
The first infection cases were monitored in **January 2019** near Flat Cay site, South of St. Thomas, most likely due to **Infected waters** transported inside the **ballast** of a ship.
Investigating the spread of the SCTLD in the USVI could help **understand its dynamics** at a regional scale and provide insights for future affected areas.





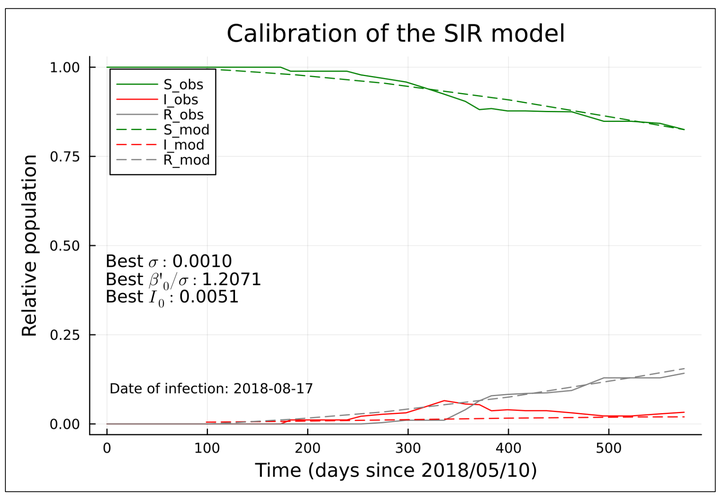
The model's unstructured mesh has a resolution ranging from 100m near coastlines and coral habitats to 2km offshore.

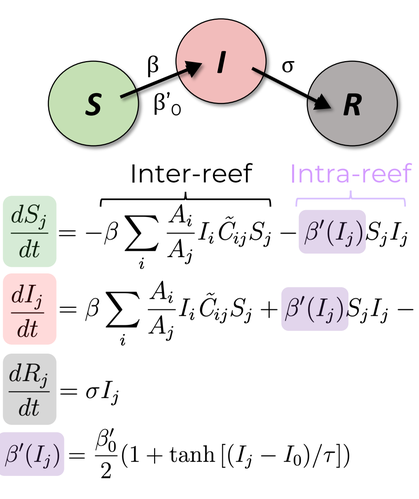




Biophysical modeling to investigate the SCTLD dynamics

The multi-scale coastal ocean model **SLIM** is used to simulate the depth-averaged hydrodynamics on the Northern USVI plateau from **January 2019 to December 2020**.
The resulting currents are used in combination with **SLIM's Lagrangian Particle Tracker** to simulate the dispersal of neutraly buoyant disease agents released continuously over the reefs. Disease agents **continuously lose mass as they are transported by the ocean currents, hence infecting the reefs they travel over**. Monthly inter-reef exchanges are stored in connectivity matrices later used in an epidemiological **Susceptible-Infected-Removed (SIR)** model.
The SIR simulation starts with a few infected reefs South of St. Thomas in January 2019. The propagation of the disease through the reefs is then computed for each month and **compared to the observed patern**.





Inter-reef | Intra-reef

$$\frac{dS_j}{dt} = -\beta \sum_i \frac{A_i}{A_j} I_i \tilde{C}_{ij} S_j - \beta'(I_j) S_j I_j$$

$$\frac{dI_j}{dt} = \beta \sum_i \frac{A_i}{A_j} I_i \tilde{C}_{ij} S_j + \beta'(I_j) S_j I_j - \sigma I_j$$

$$\frac{dR_j}{dt} = \sigma I_j$$

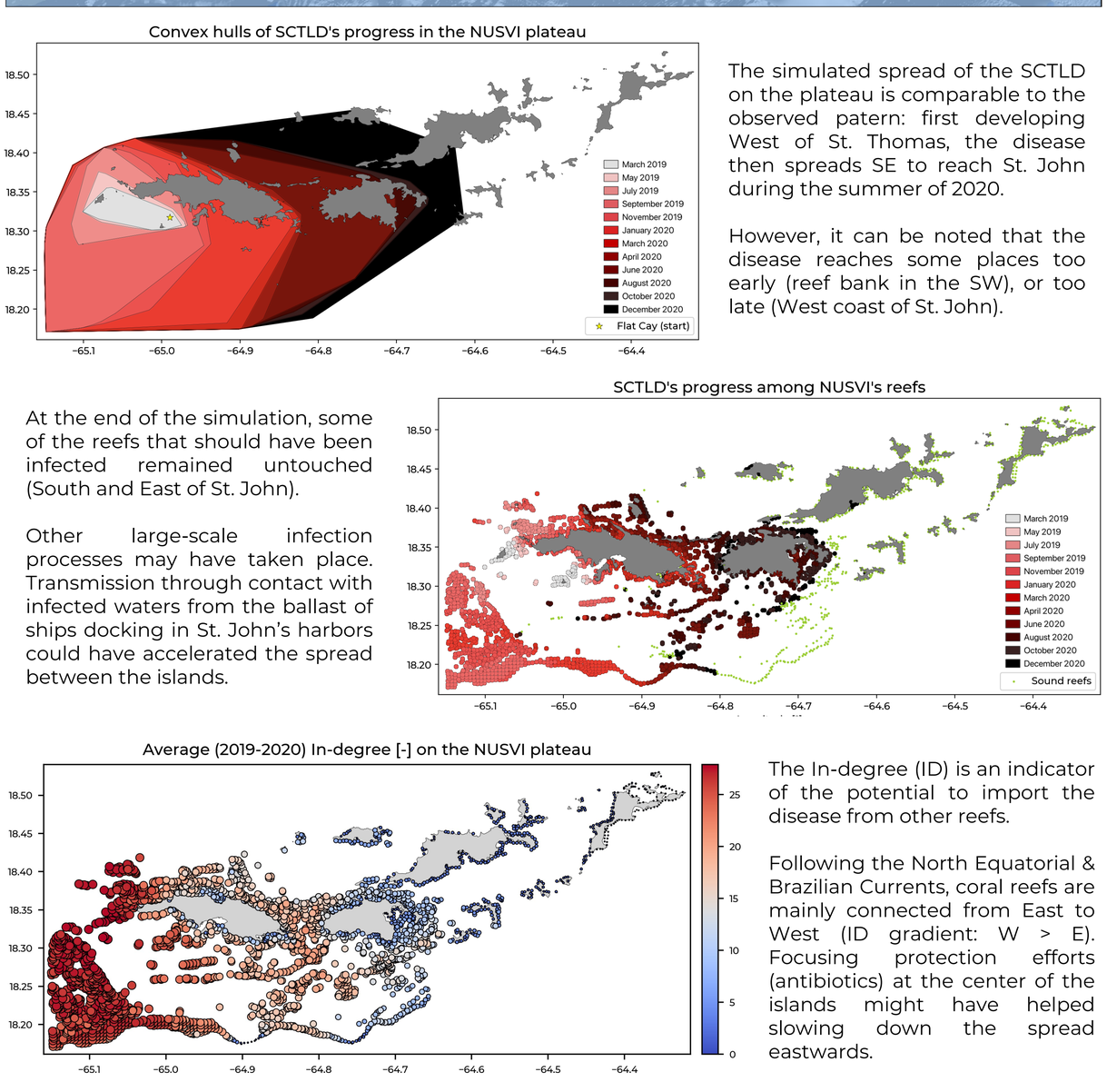
$$\beta'(I_j) = \frac{\beta'_0}{2}(1 + \tanh\left[(I_j - I_0)/\tau\right])$$

SIR calibration using field measurements from the Florida Keys

The SIR model is calibrated with SCTLD prevalence data gathered at 6 monitoring sites in the Florida Keys from May 2018 to December 2019.
As the species distribution in the USVI is slightly different from the one in Florida, the model was fit to a weighted (by relative abundance) **average of the most represented species in the area.**

The considered species included several corals with **various susceptibilities to the SCTLD**: *Orbicella spp.*, *M. cavernosa*, *S. siderea*, *P. strigosa*, and *P. astreoides*.

A squared error minimization allowed us to compute the best fit for the mortality rate **(σ)**, intra-reef base transmission **(β'_0)** and intra-reef infection threshold **(I_0)**.



The simulated spread of the SCTLD on the plateau is comparable to the observed patern: first developing West of St. Thomas, the disease then spreads SE to reach St. John during the summer of 2020.

However, it can be noted that the disease reaches some places too early (reef bank in the SW), or too late (West coast of St. John).

At the end of the simulation, some of the reefs that should have been infected remained untouched (South and East of St. John).

Other large-scale infection processes may have taken place. Transmission through contact with infected waters from the ballast of ships docking in St. John's harbors could have accelerated the spread between the islands.

The In-degree (ID) is an indicator of the potential to import the disease from other reefs.

Following the North Equatorial & Brazilian Currents, coral reefs are mainly connected from East to West (ID gradient: W > E). Focusing protection efforts (antibiotics) at the center of the islands might have helped slowing down the spread eastwards.

Next steps

- Simulating the hydrodynamics with SLIM3D and extending to the entire USVI basin.
- Adjusting coral habitats map and accounting for species distribution and susceptibility to the SCTLD in the SIR model.
- Producing sensitivity analyses for the buoyancy of the disease agents.

Take-home messages

- The matching paterns indicate that water-borne disease agents may have supported the spread of the SCTLD in the USVI.
- Other large-scale processes may have helped propagate the disease to remote locations.
- Some areas can play an important role in the disease spread and should be the first targets of conservation efforts.

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