Rising green tides and golden tides: An oceanographic regime shift?

Chuanmin Hu, University of South Florida

huc@usf.edu, https://optics.marine.usf.edu

Co-authors and collaborators:

Mengqiu Wang, Lin Qi, Brian Barnes, Brock Murch, Robert Hardy, Brian Lapointe, Amy Sinuda, Jean-Philippe Maréchal, Jim Franks, Shaoling Shang, Cara Wilson, Lianbo Hu, Ming-Xia He, Qianguo Xing……

What green tides and golden tides?
Reports around the world

Top: *Ulva* green tides in Brittany, France (left) and Qingdao, China (right)
Bottom: *Sargassum* golden tides in Antigua Caribbean (left) and Texas, USA (right)
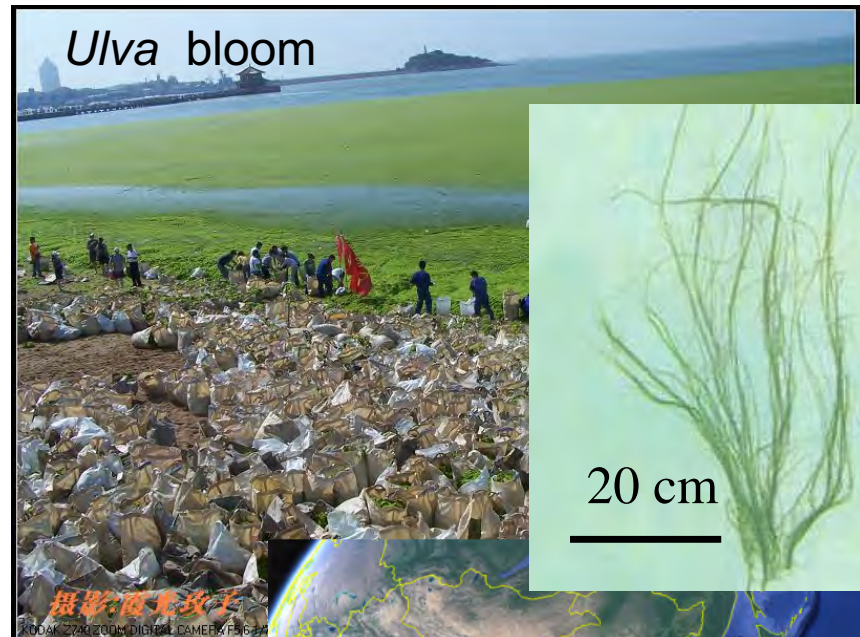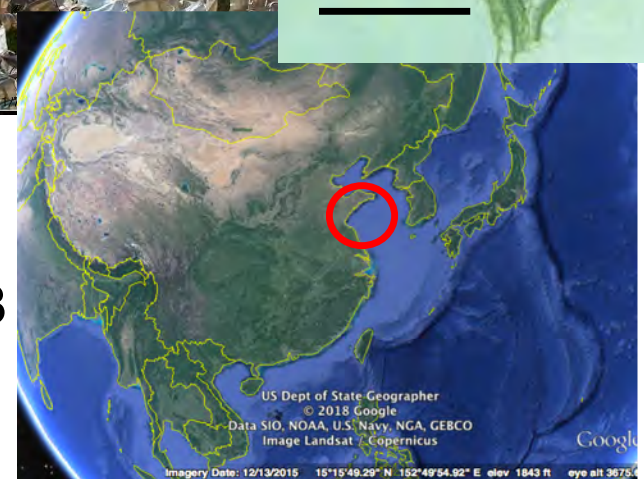

Credit: (Smetacek and Zingone, 2013)

What green tides and golden tides?

Ulva blooms off Qingdao and in the Yellow Sea

June 2018, Olympic sailing game

Ulva bloom

20 cm

> 10,000 Volunteers, >1,000 vessels, aircrafts
> 700,000 tons algae collected by mid July 2008
> 30 km containment booms to block algae

What green tides and golden tides?
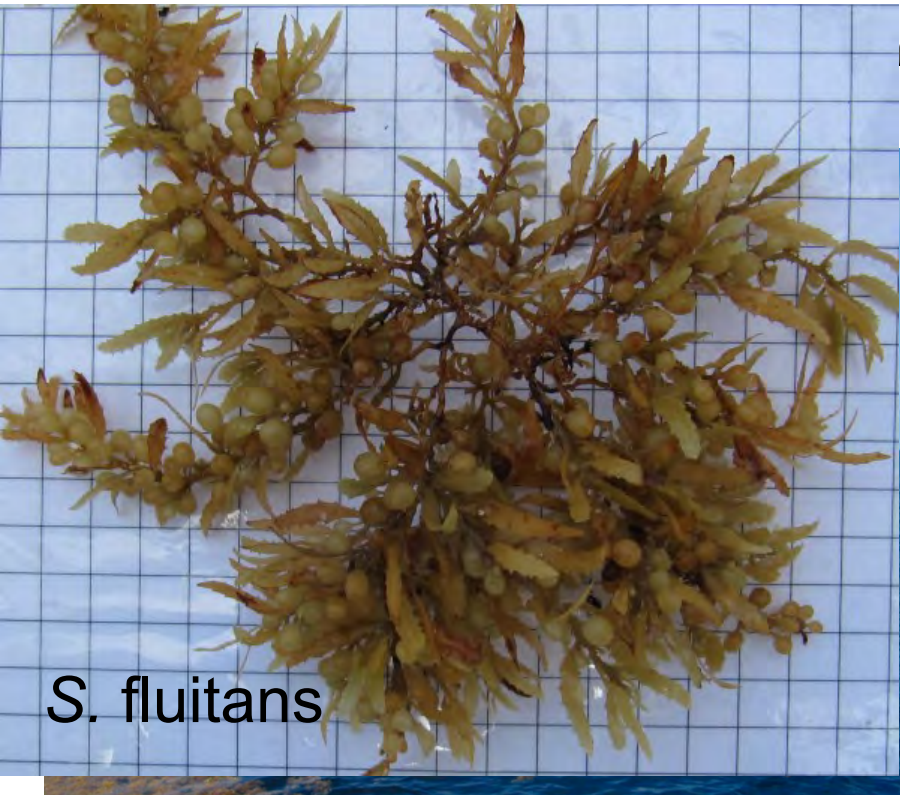## *Sargassum* blooms in the East China Sea

Sargassum horneri
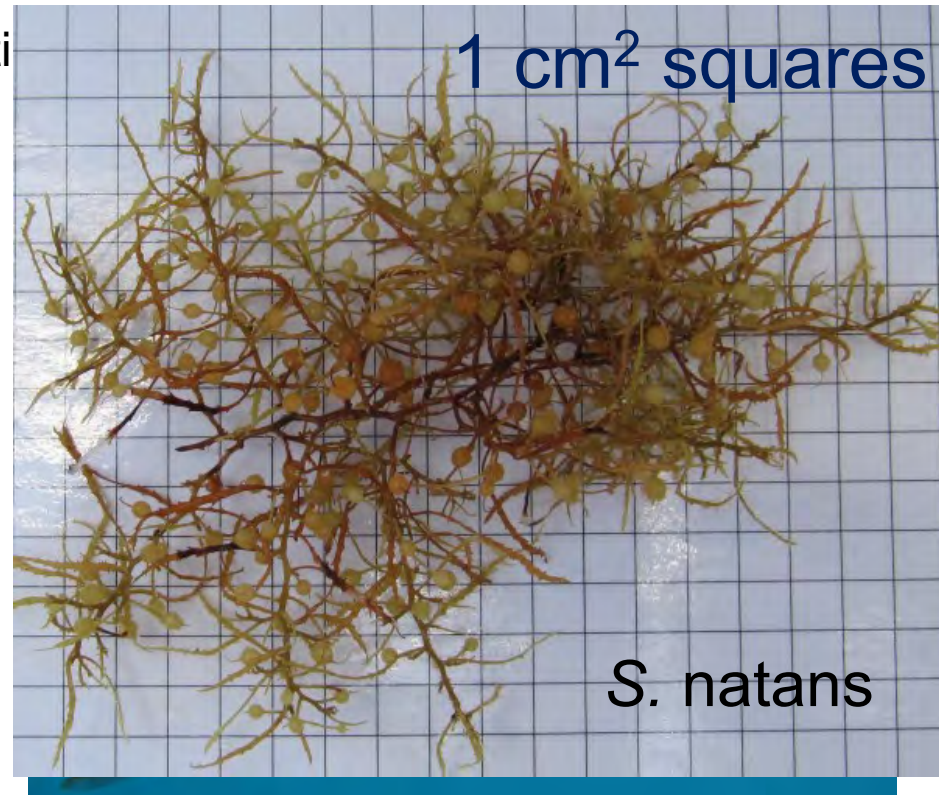
What green tides and golden tides?

Sargassum blooms in the Caribbean Sea

An important habitat

▪Food and shade to many animals (fish, young turtles, shrimp, crab, etc.), and it also supports sand dunes and shoreline stabilization

S. fluitans

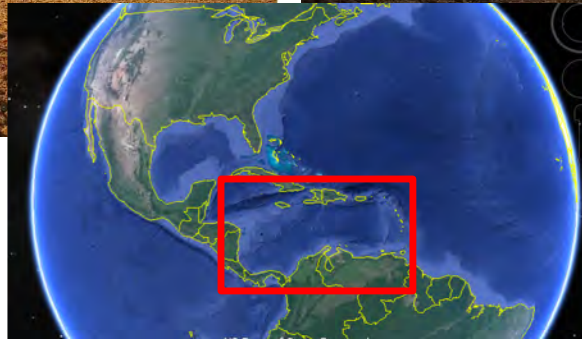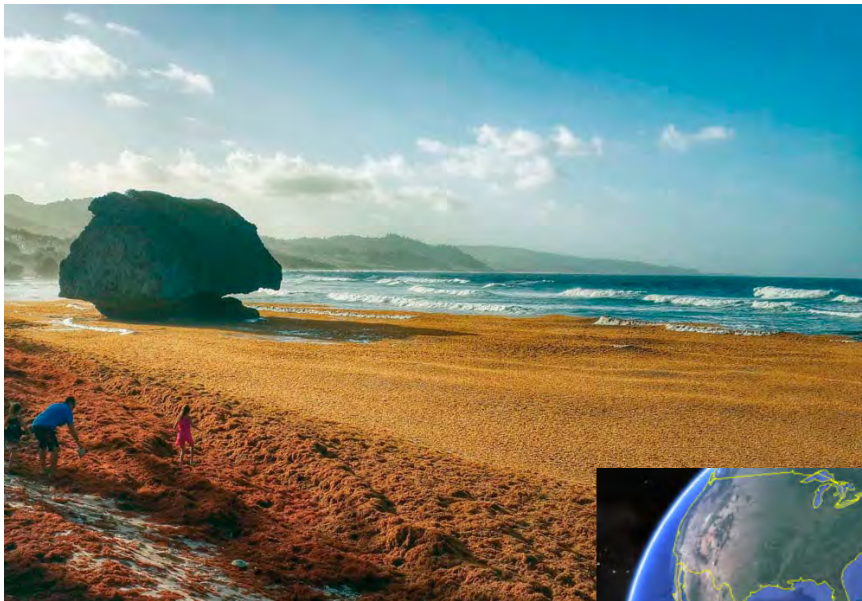1 cm^2 squares

S. natans

What green tides and golden tides?
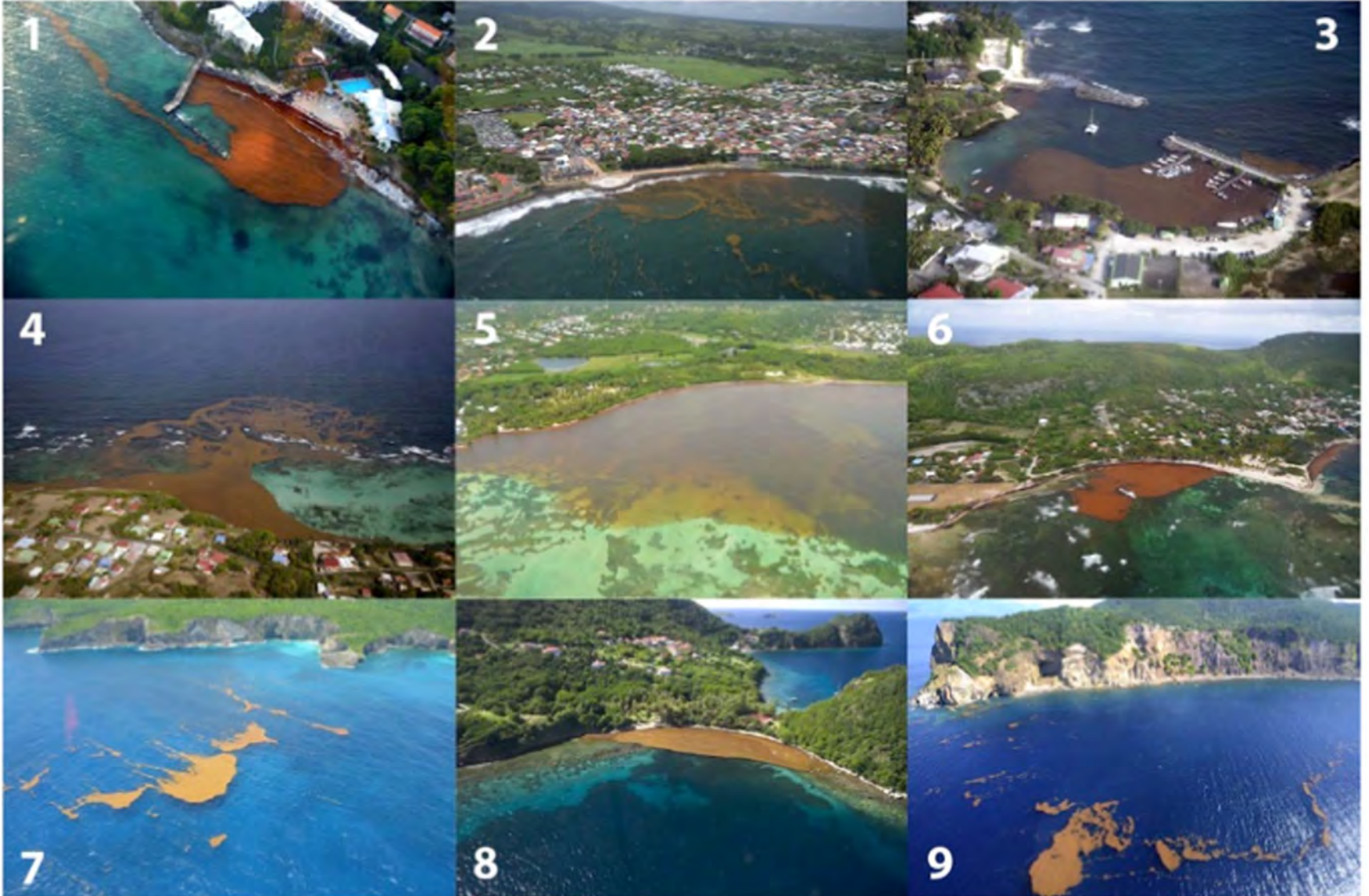
Sargassum blooms in the Caribbean Sea

A beach nuisance

- Smells bad, attracts insects,

- Smother turtle nesting sites, causing turtle and fish mortality

- Negative impact on tourism and economy

What green tides and golden tides?

Sargassum blooms in the Caribbean Sea

What green tides and golden tides?
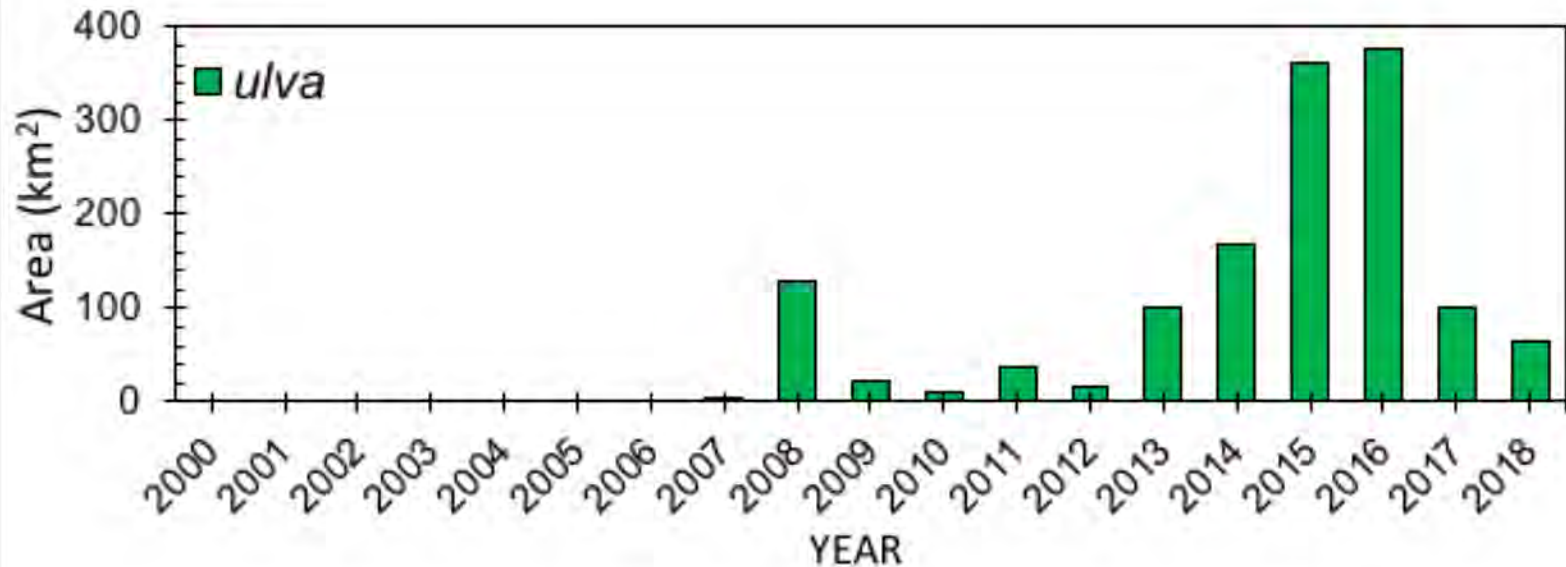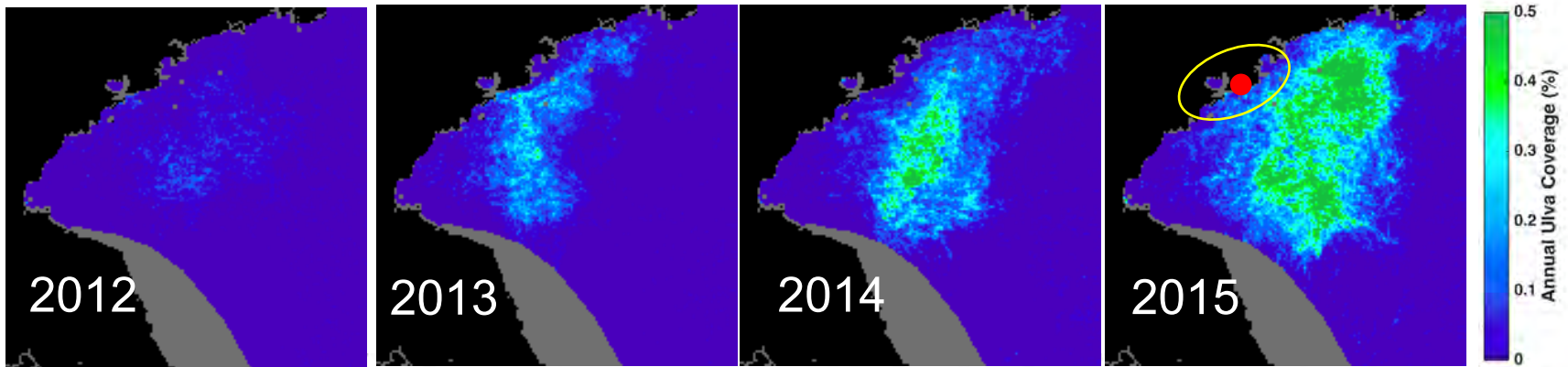
Sargassum blooms in the Caribbean Sea

From Dirk Aurin

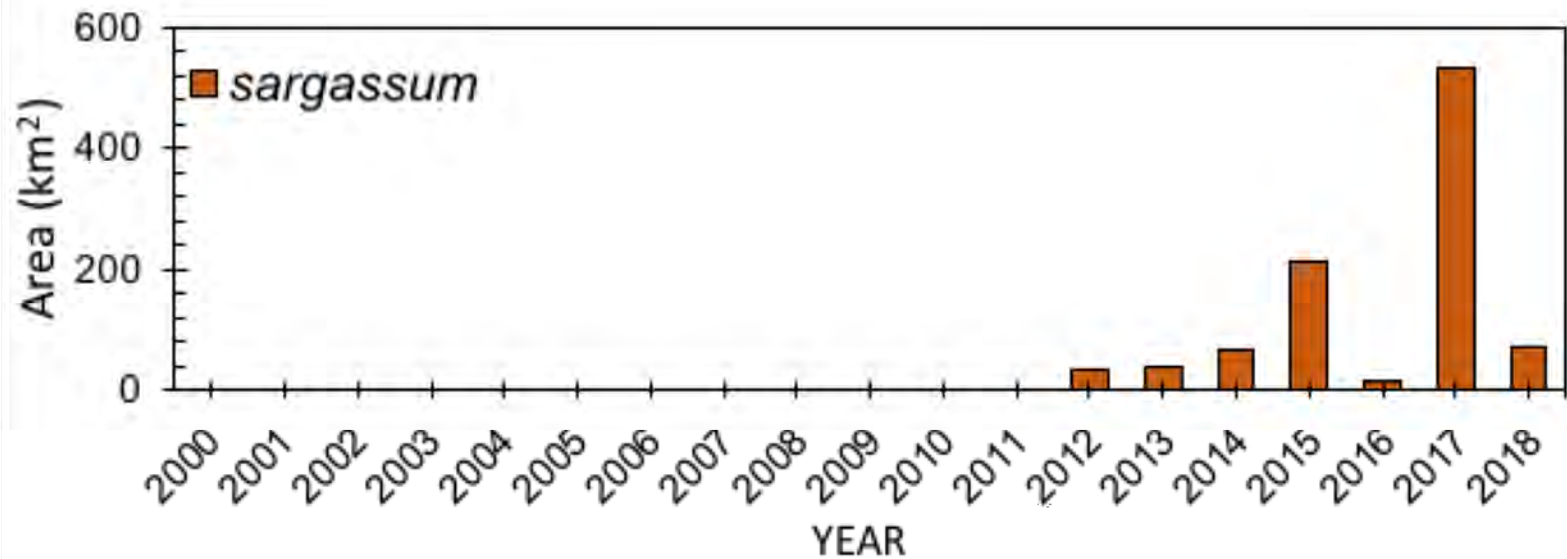# Any historical trends?

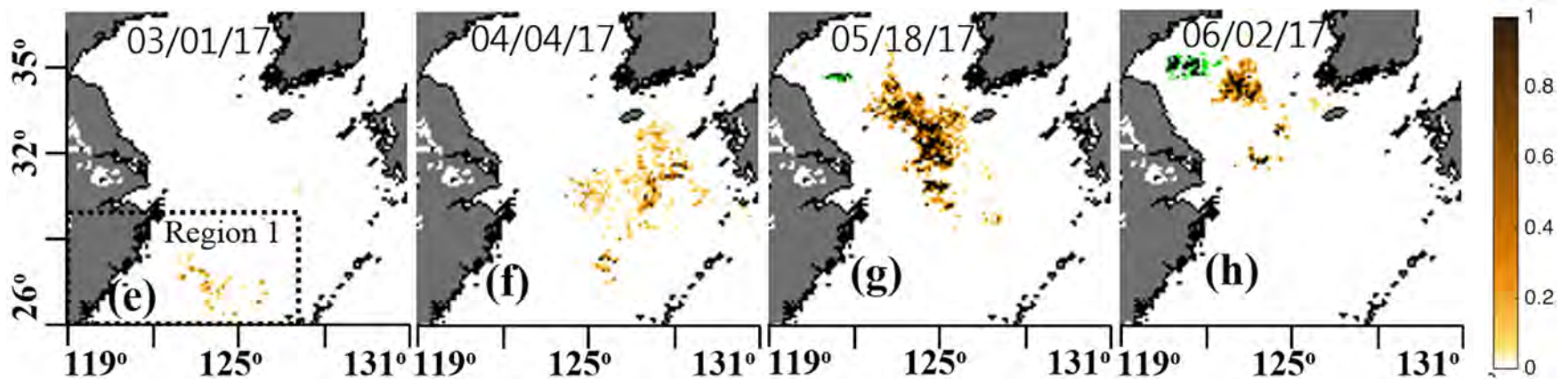## *Ulva* blooms in the Yellow Sea

MODIS time series (Qi et al., 2016, HA)

Any historical trends?
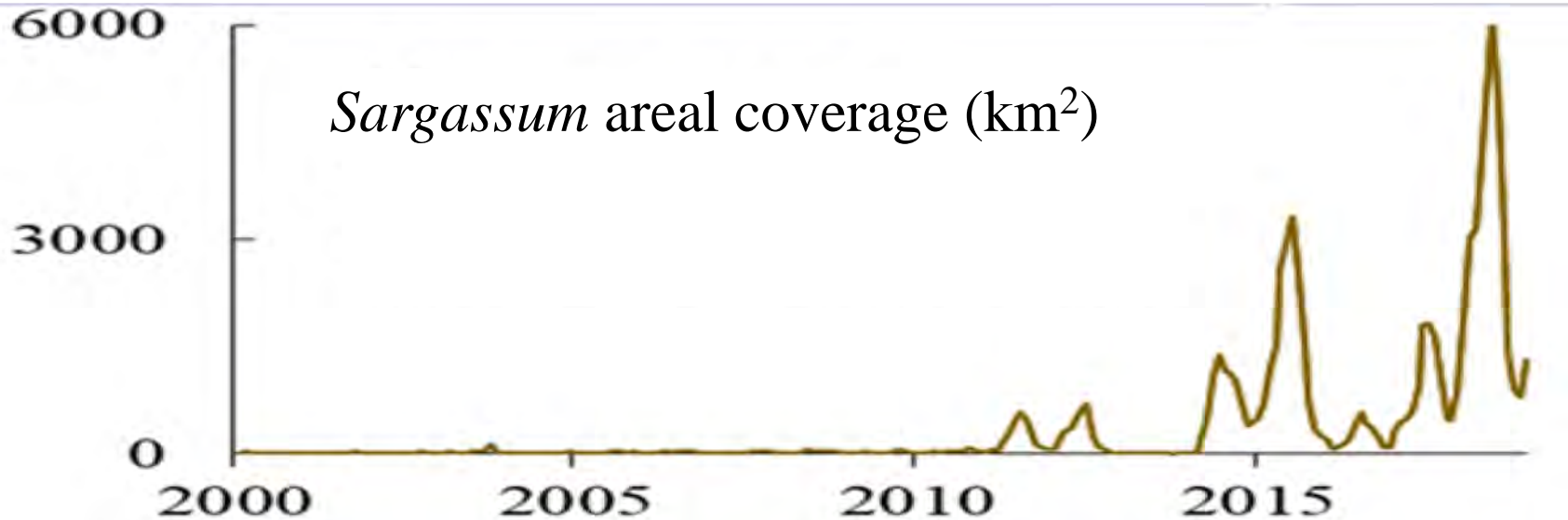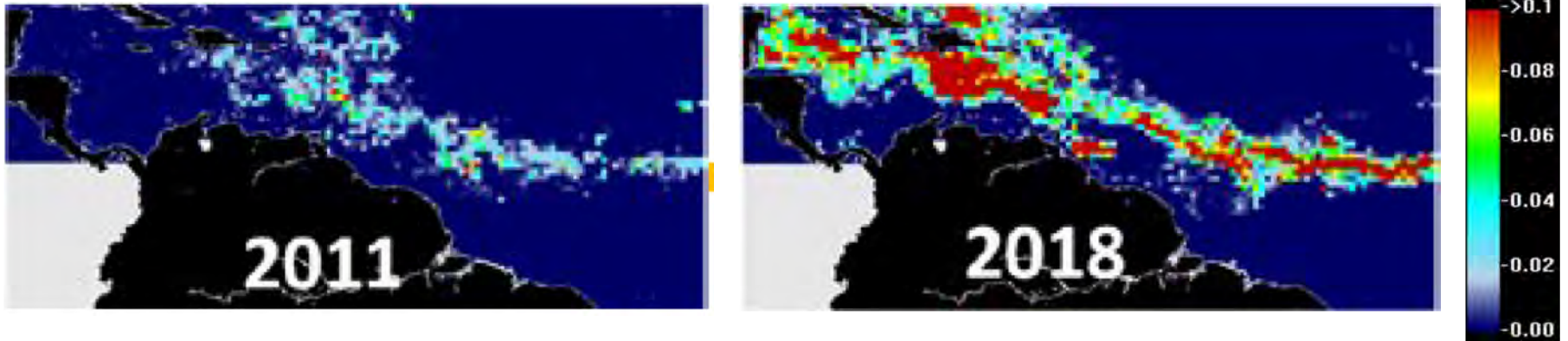
Sargassum blooms in the East China Sea

MODIS time series (Qi et al., 2017, GRL)
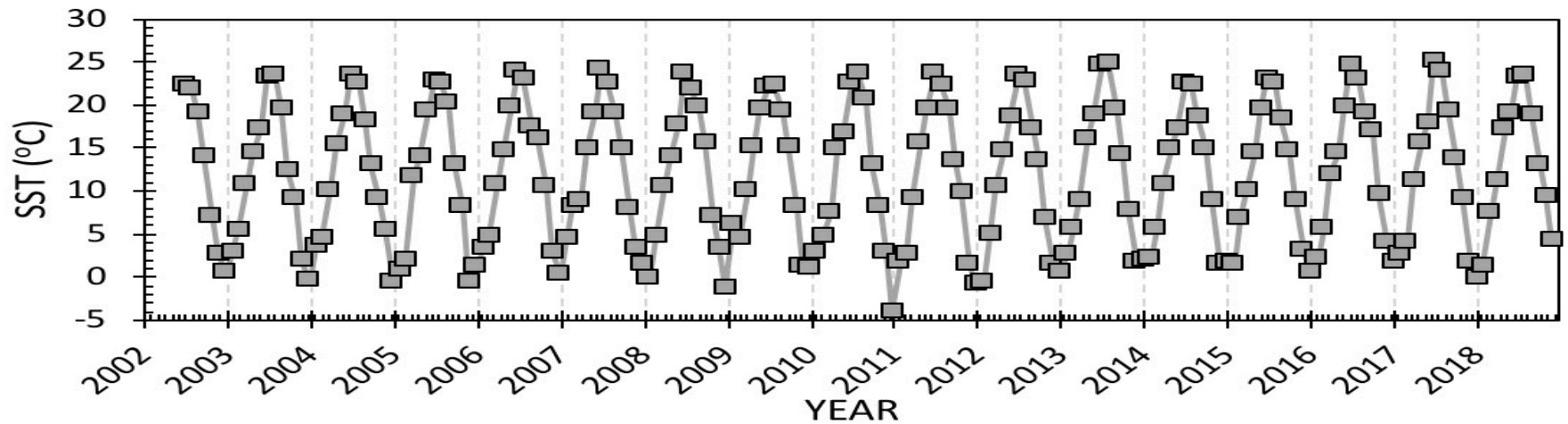
Any historical trends?

Sargassum blooms in the Atlantic and Caribbean

MODIS time series (Wang, 2018)
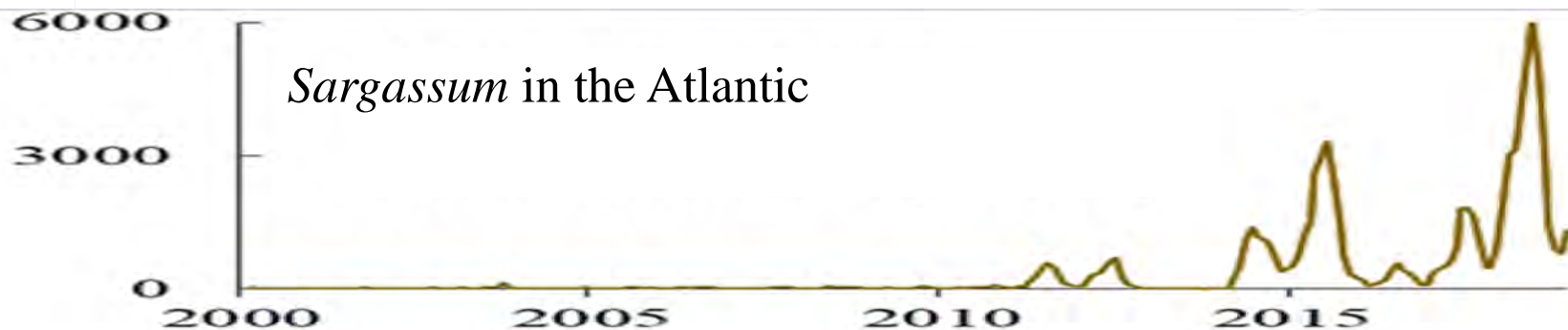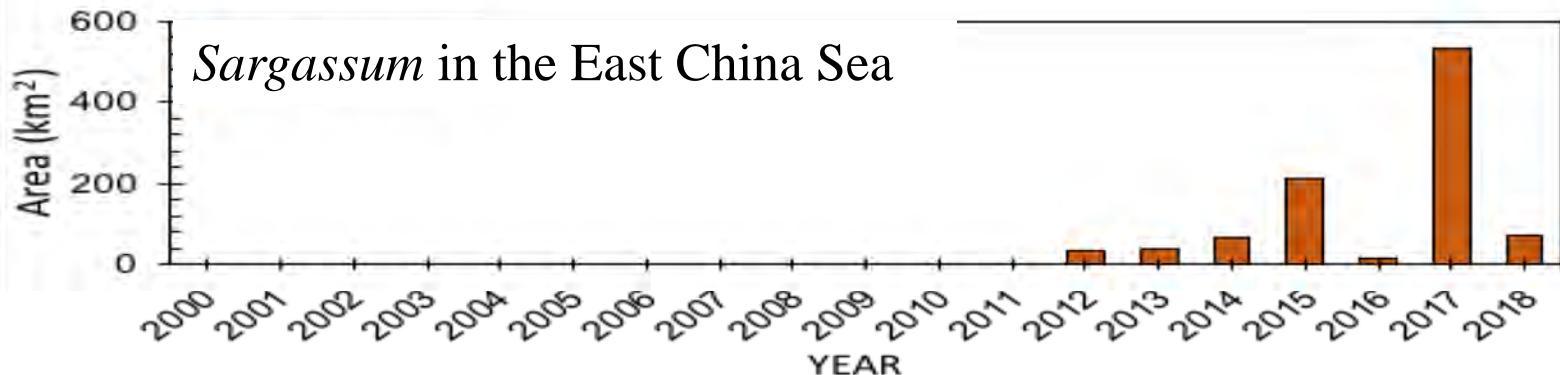

Sargassum areal coverage (km^2)

A regime shift?

No other properties show such dramatic changes

A regime shift?

No other properties show such dramatic changes

Ulva in the Yellow Sea

Sargassum in the East China Sea

Sargassum in the Atlantic
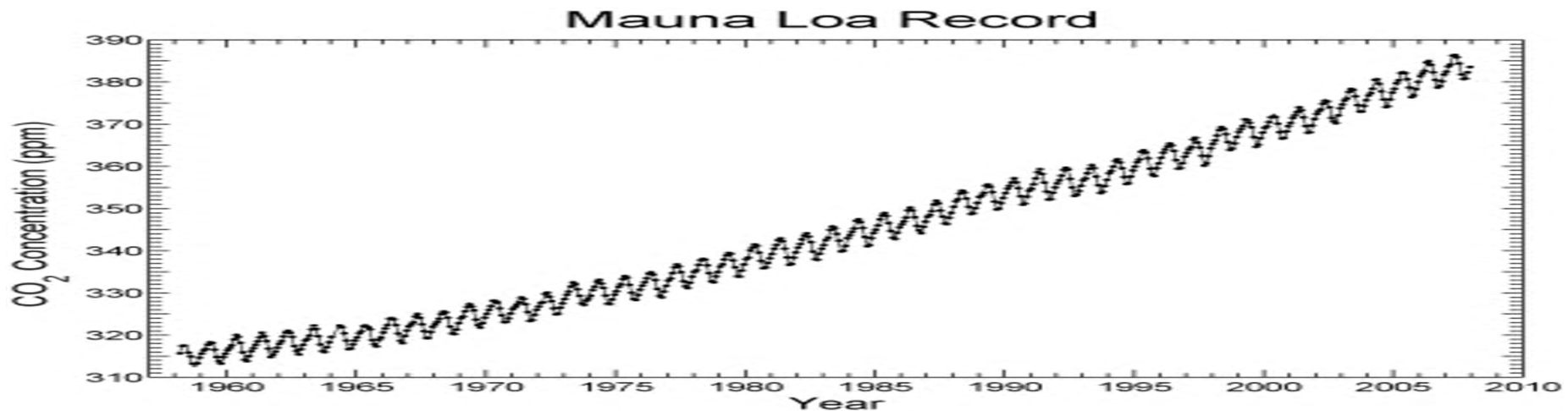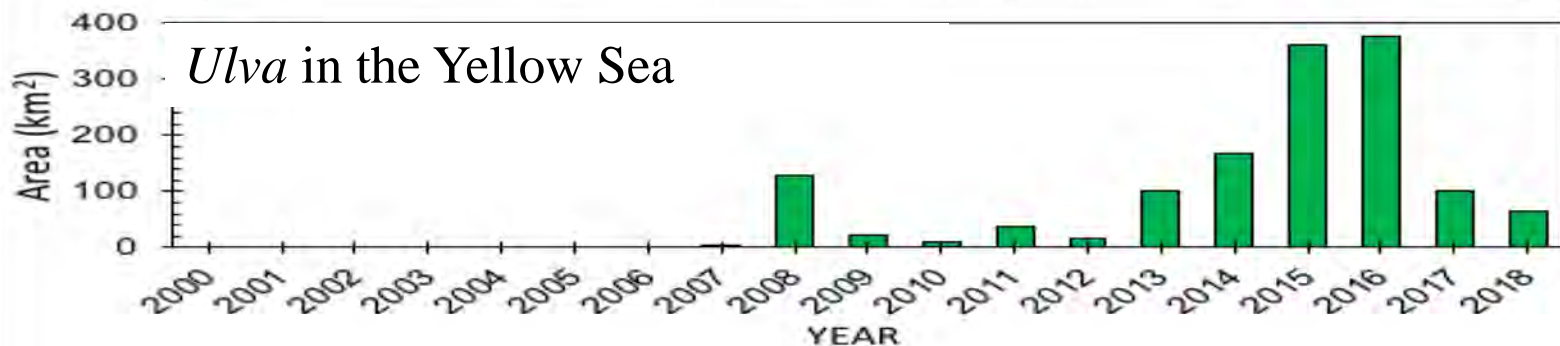
What caused *Ulva* blooms in the YS?
Coastal seaweed aquaculture
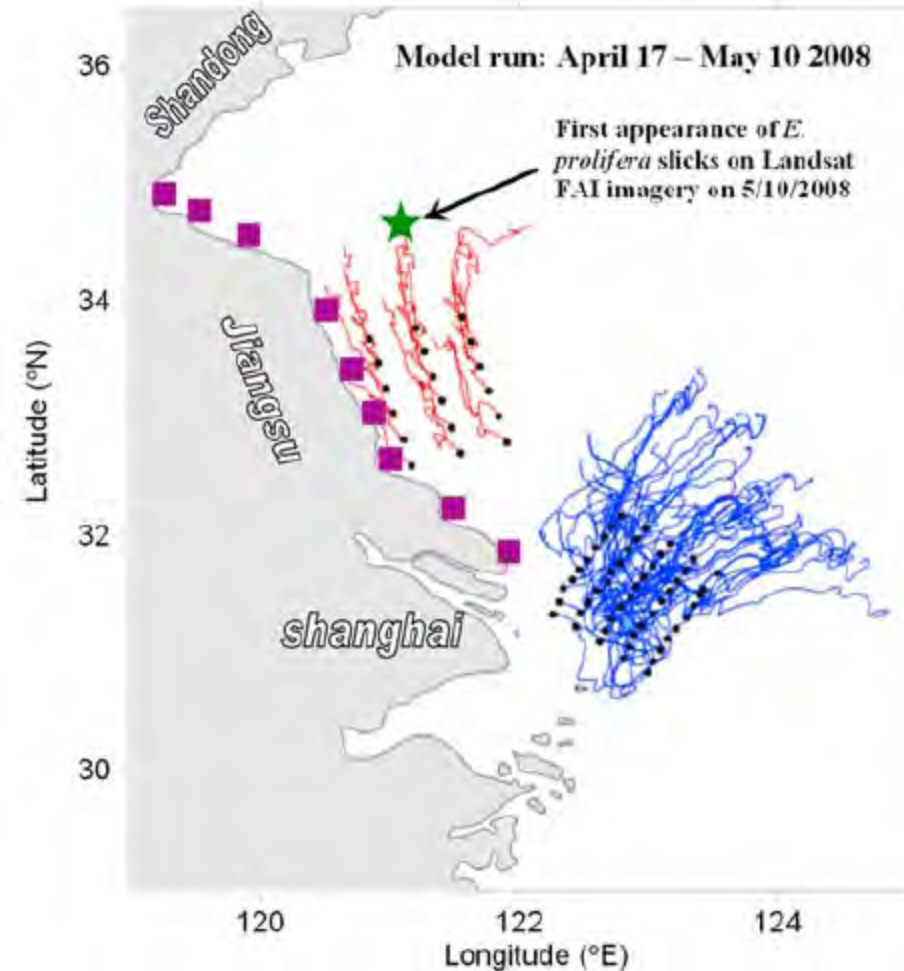
Hu et al., (2010, JGR)
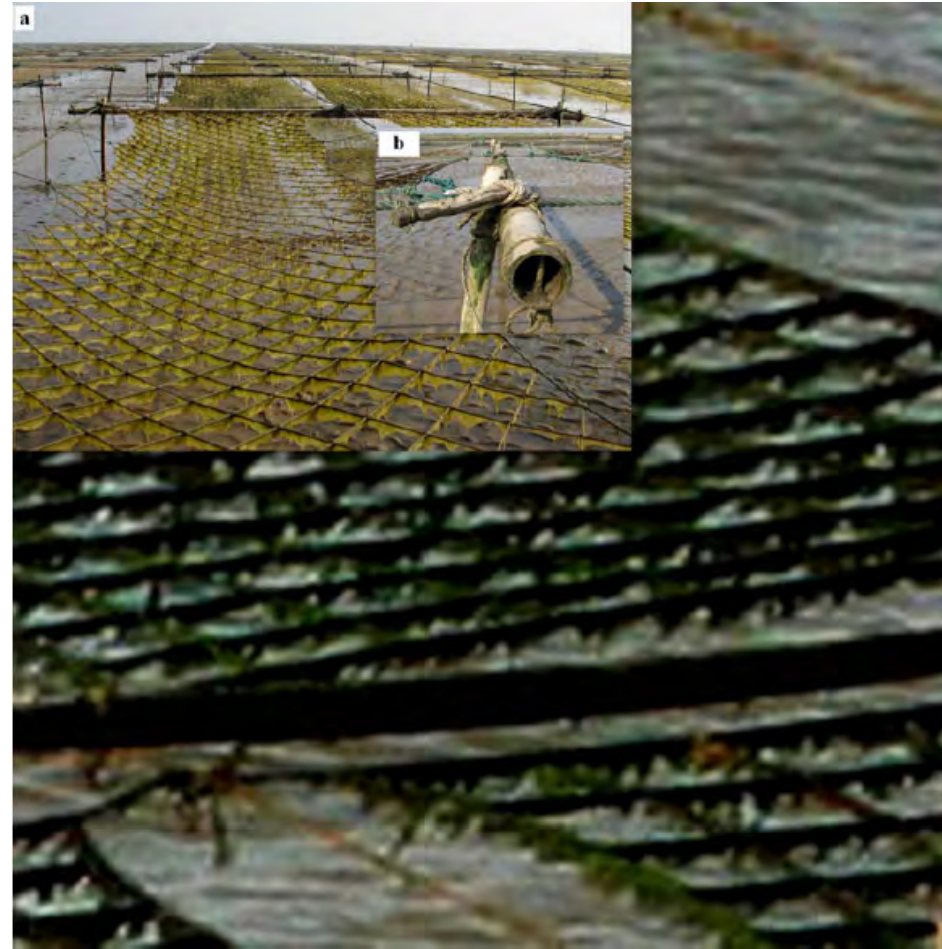
Liu et al., (2009, MPB)

What caused *Sargassum* blooms in the ECS?
Coastal seaweed aquaculture & environmental changes

Numerical tracking
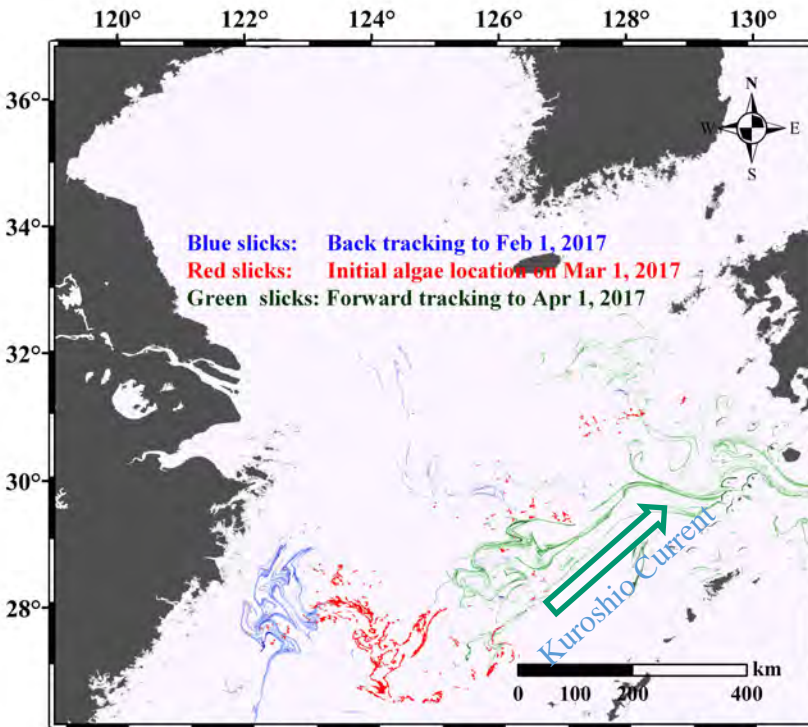
Top: Aquaculture area
Bottom: surface temperature anomaly
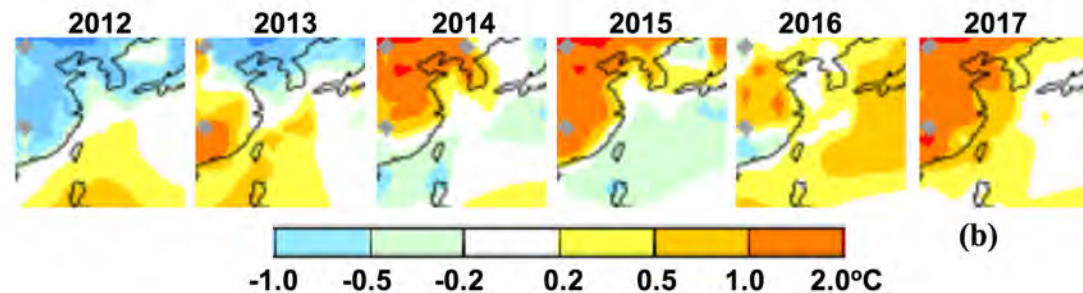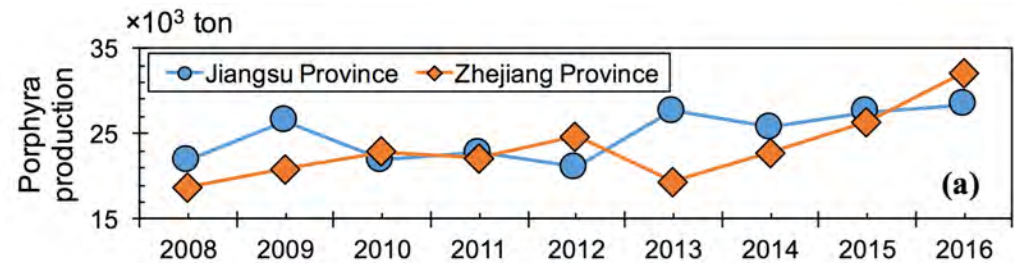
Qi et al. (2017, GRL)

What caused *Sargassum* blooms in the Atlantic?

Some hypotheses, but picture not clear

- Water temperature?
- Light?
- Precipitation?
- Dust deposition?
- Amazon River?

Dust deposition anomaly
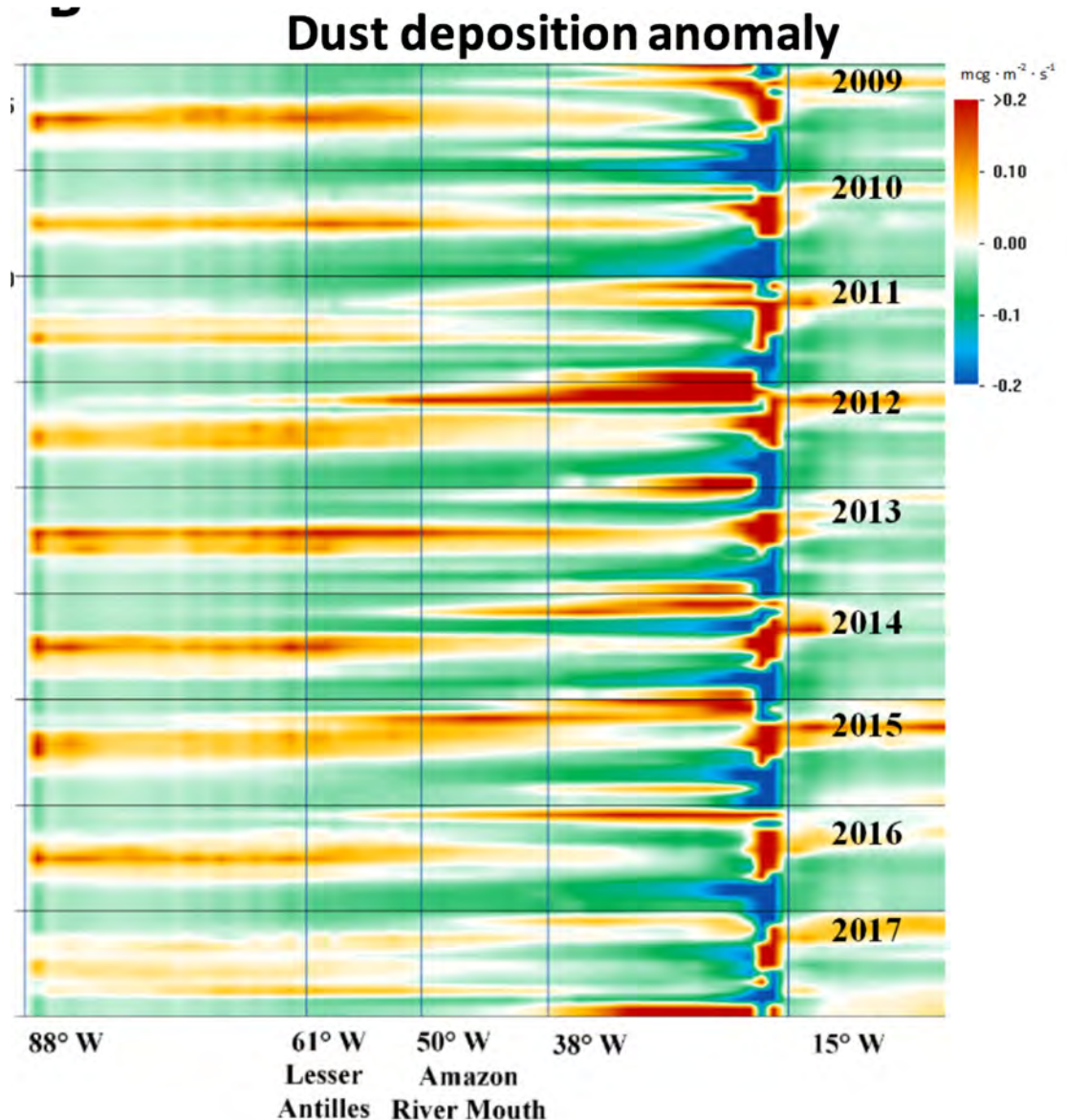
What caused *Sargassum* blooms in the Atlantic?

Some hypotheses, but picture not clear

The vast ocean is connected through ocean currents
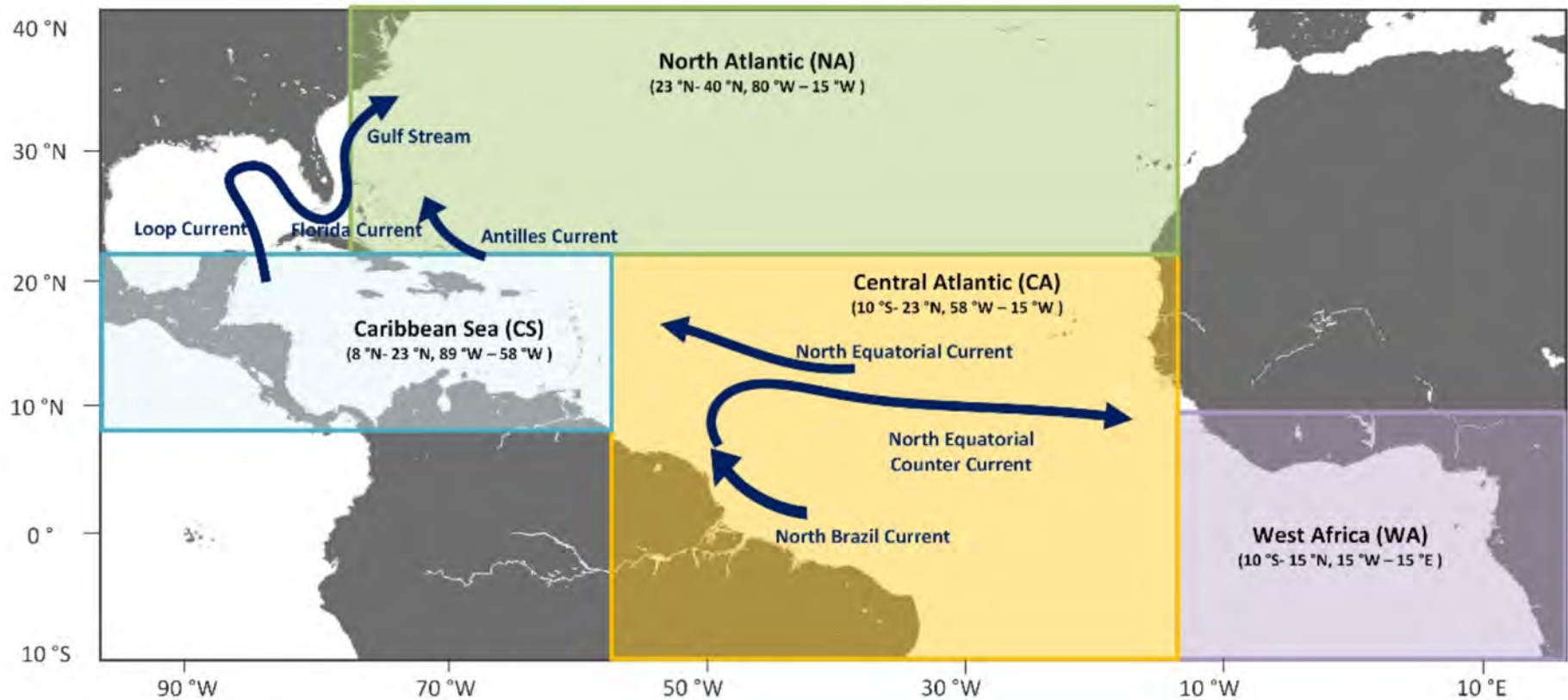
So what?

Long-term and short-term prediction?
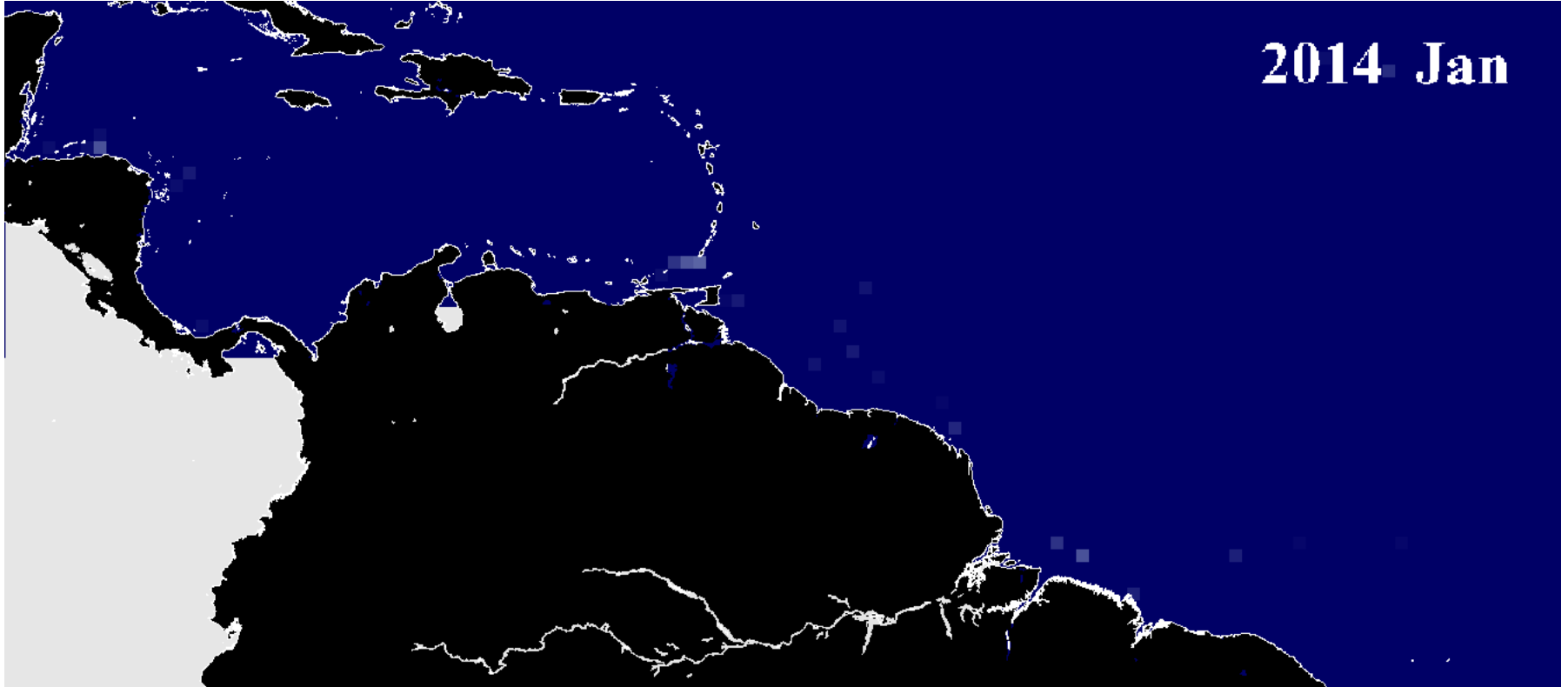
Wang and Hu (2017, GRL)

So what?

Long-term and short-term prediction?

West Palm Beach

June 2018

So what?

Long-term and short-term prediction?

Qingdao beach, July 2010

So what?

Long-term and short-term prediction?

Real-time monitoring and tracking: https://optics.marine.usf.edu/

So what?

Near real-time applications

NOAA/FWC turtle rehabilitation program
During Hurricane Irma, over 2,500 hatchlings were washed ashore and later placed on *Sargassum* mats.

So what?

Biogeochemistry, ecology, environment, economy

C,N,P, and pigments per dry weight of *Sargassum*
Pigments: ng per mg dry weight

	%C	%N	%P	Chl-a	Chl-c
All	27.16 ± 2.23	1.06 ± 0.31	0.10 ± 0.03	485.20 ±101.28	39.36 ± 6.69
Neritic	27.76 ± 2.19	1.00 ± 0.31	0.10 ± 0.03	NAN	NAN
Oceanic	25.59 ± 7.60	1.19 ± 0.26	0.11 ± 0.03	NAN	NAN

Sargassum carbon accounts for 6 - 8% of total POC in the
Tropical Atlantic and Caribbean Sea during peak months
(Wang et al., 2018)

So what?

Biogeochemistry, ecology, environment, economy

Video from Manolo Despradel (Dominican Republic)

So what?

Biogeochemistry, ecology, environment, economy

House made of *Sargassum* bricks

So what?

Biogeochemistry, ecology, environment, economy

Eco-shoes made with *Sargassum* and plastic bottles

Rising green tides and golden tides: An oceanographic regime shift?

Summary

- Both *Ulva* and *Sargassum* in the YS, ECS, and Atlantic show dramatic increases in recent years, indicating a possible regime shift

- The reasons can be both natural and unnatural, but exact reason for the Atlantic *Sargassum* still unclear

- Recurrent blooms may become a new norm in future years, calling for more studies and management actions

Now what?

Regime shift leads to algorithm paradigm shift?
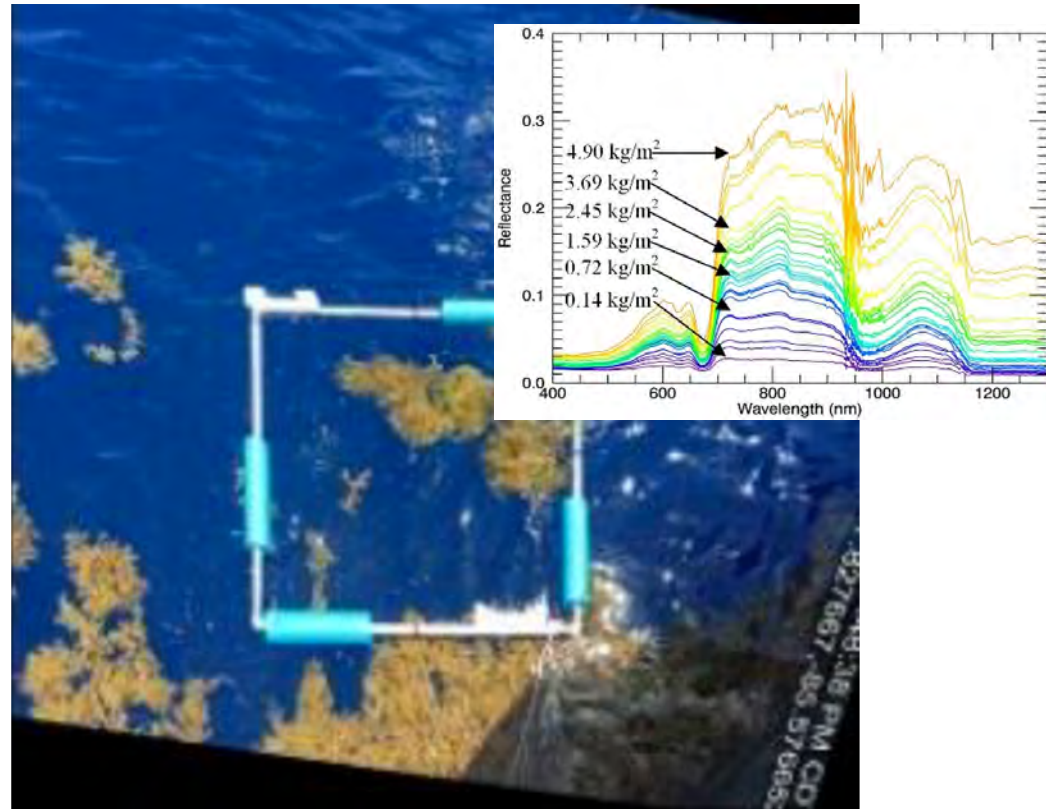## Algorithm design

All maps are based on the floating algae index (FAI) concept
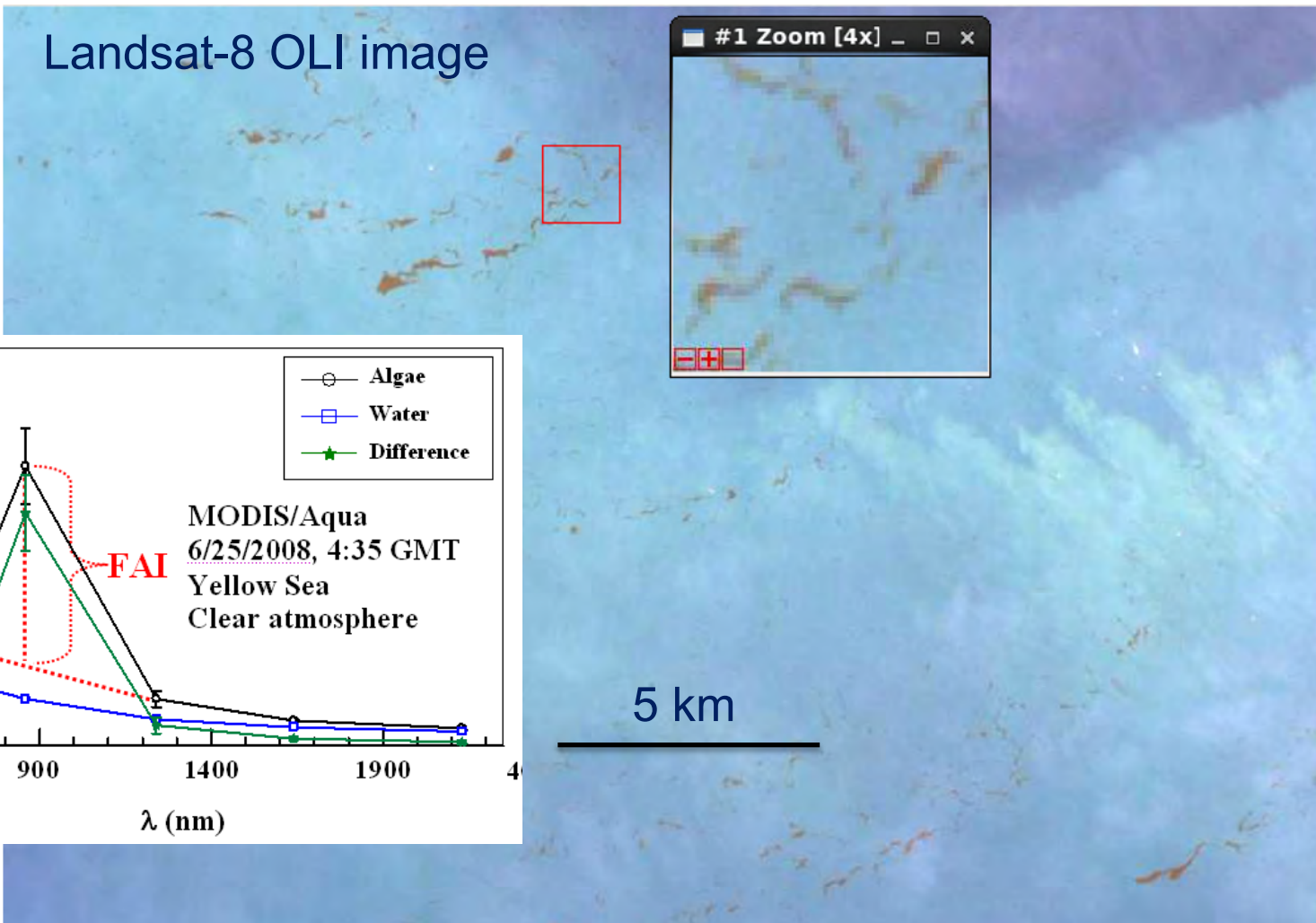
Regime shift leads to algorithm paradigm shift?
Field measurement, algorithm tuning, and validation

### Reflectance and biomass measurements

Wang et al. (2018, GRL)

Regime shift leads to algorithm paradigm shift?
From band ratio to band difference for Chl

- CI = f(Chl) for Chl < 0.4 mg m^{-3}
- CI is immune to spectrally flat and additive input R_{rs} errors
- Significantly reduced uncertainties and improved cross-sensor consistency for low-Chl waters
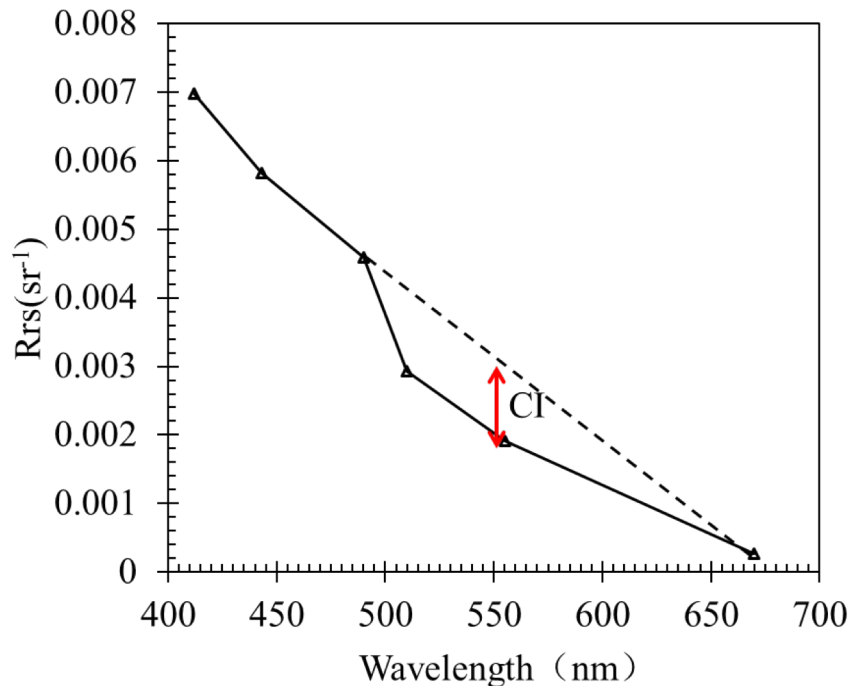- CI became default SeaDAS algorithm for low-Chl waters starting R2014.0

$\mathbf{CI} = f(\mathrm{Chl})$
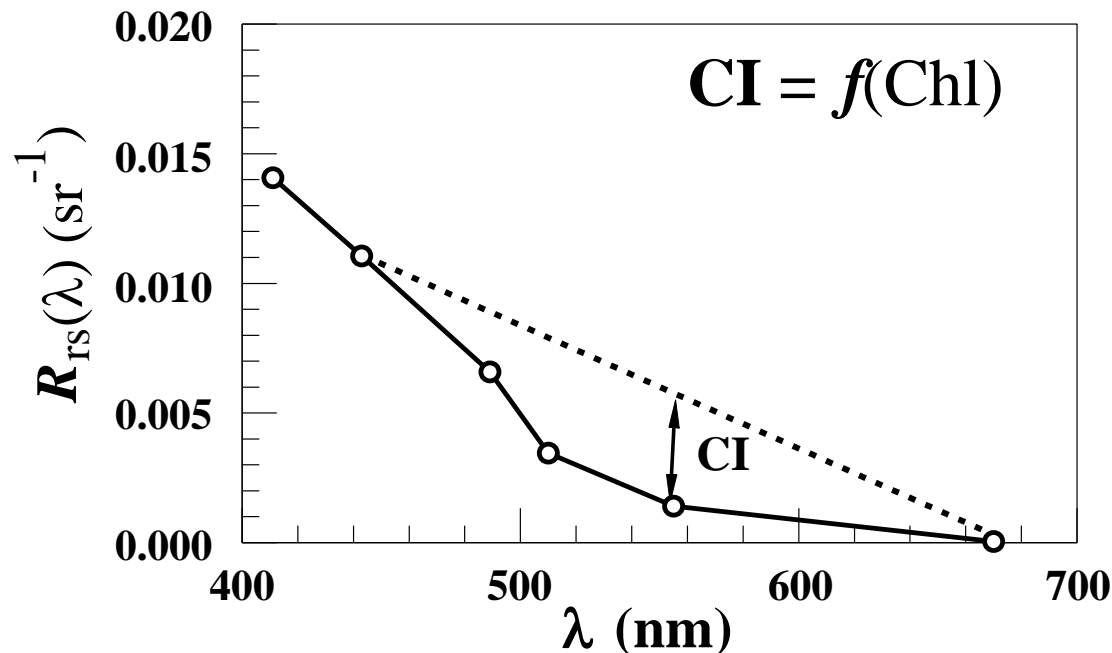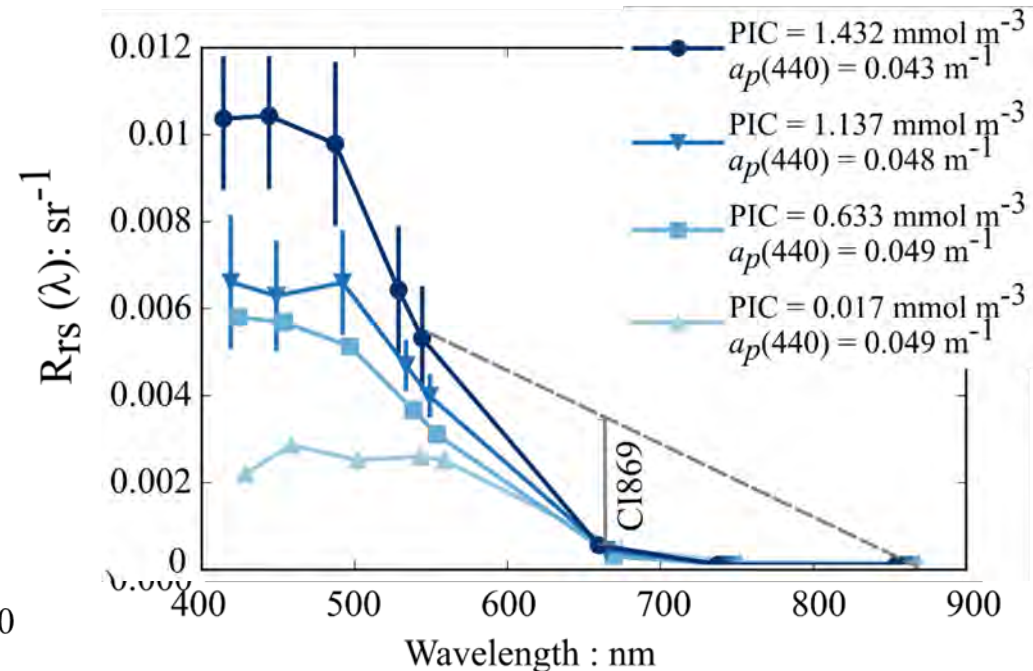
Hu et al., 2012 & 2019

Regime shift leads to algorithm paradigm shift?
New concept applied to POC and PIC

CI$_{POC}$ improves over previous algorithms (Le et al., 2018)

CI$_{PIC}$ improves over previous algorithms (Mitchell et al., 2017)

But why?

Regime shift leads to algorithm paradigm shift?
New concept applied to Chl, POC, and PIC

Conclusions

- The concept of quantifying macroalgae has been extended to Chl, PIC, and POC, each showing improvements over previous empirical algorithms

- Connectivity is beyond spatial and temporal, but can be conceptual

- Research is full of (pleasant) surprise!