Climate and anthropogenic controls of seaweed expansions in the East China Sea and Yellow Sea

Lin Qi (lin.qi@noaa.gov);
NOAA STAR Ocean Color Science Team

Co-authors and collaborators:
Menghua Wang (NOAA STAR)
Chuanmin Hu (University of South Florida)
Many others…

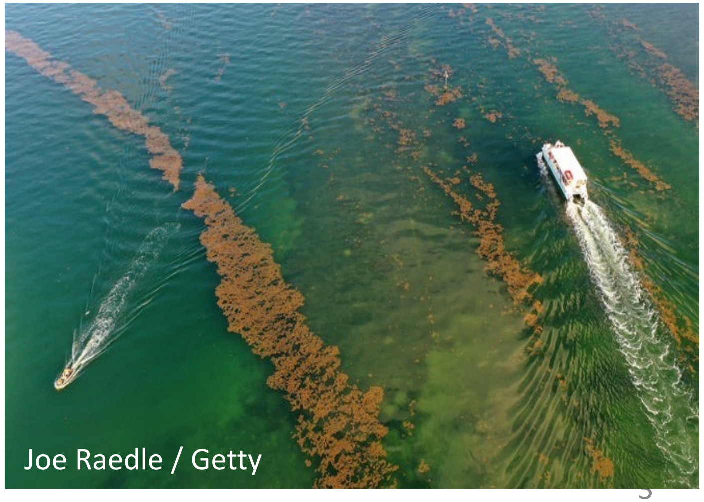
Outline

1. Background - what are the problems?
2. Methodology – how do we address them?
3. Findings – climate change or human activities?
4. So what – implications for future studies?

1. Background – what are the problems?

Seaweed (macroalgae) blooms have been reported around the world

Green and brown seaweed blooms in France, China, Caribbean Islands, USA, …



1. Background – what are the problems?

Seaweed (macroalgae) blooms have been reported around the world

Green and brown seaweed blooms in France, China, Caribbean Islands, USA, …

The good – An important habitat

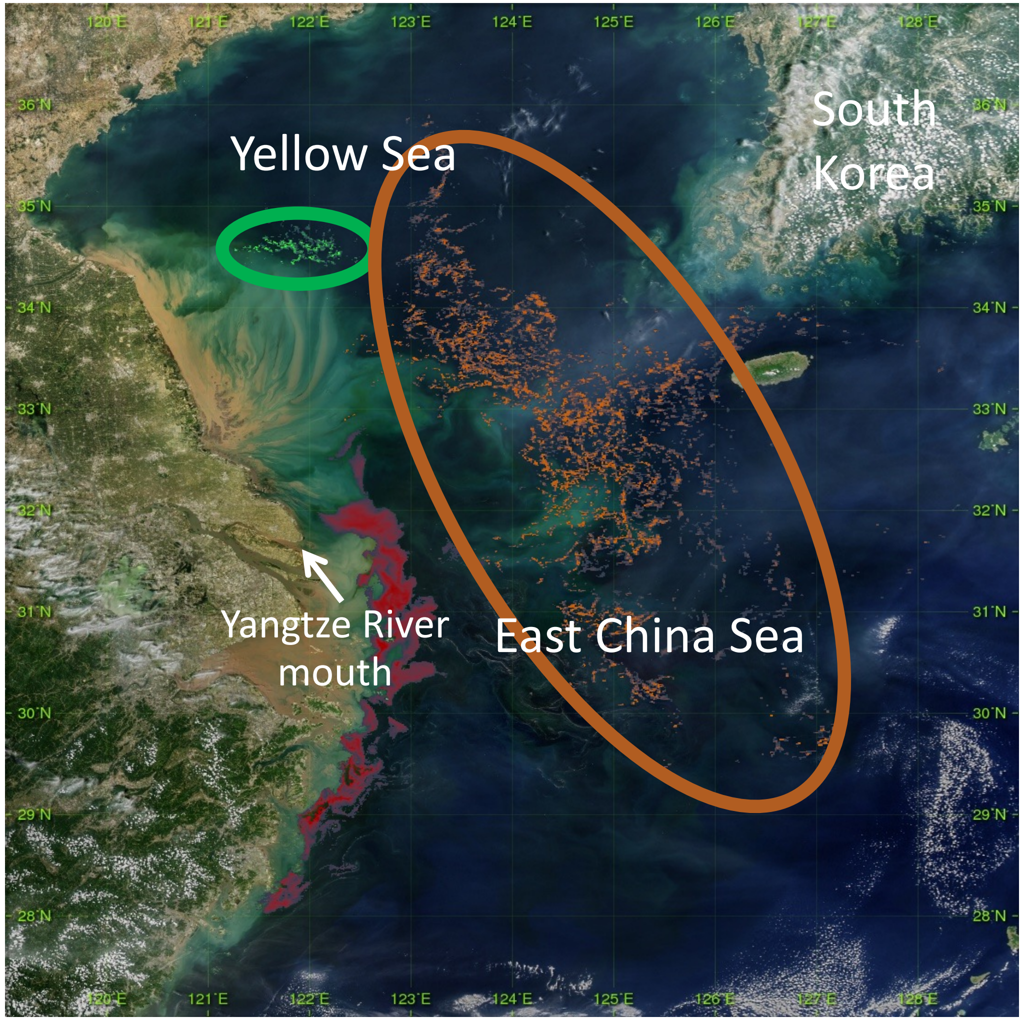
- They may provide shade and serve as habitat to many animals (fish, young turtles, shrimp, crab, etc.), and can also support sand dunes and shoreline stabilization
- They also play important roles in carbon cycling and other nutrient cycling

The bad – A beach and environmental nuisance

- Smell bad, attract insects.
- Smother turtle nesting sites, causing turtle and fish mortality
- Negative impact on tourism and economy

1. Background – what are the problems?

Two distinct seaweed blooms occurred in the Chinese marginal seas

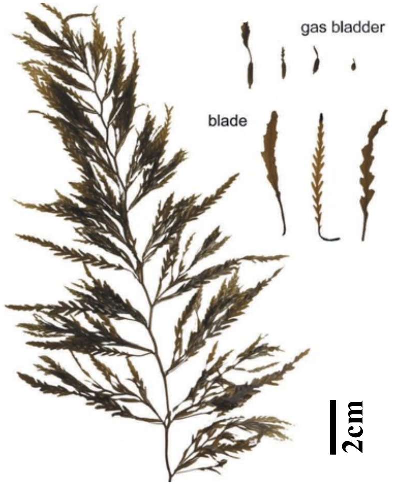


Ulva prolifera

Li et al., (2023)

Green tide

Sargassum horneri



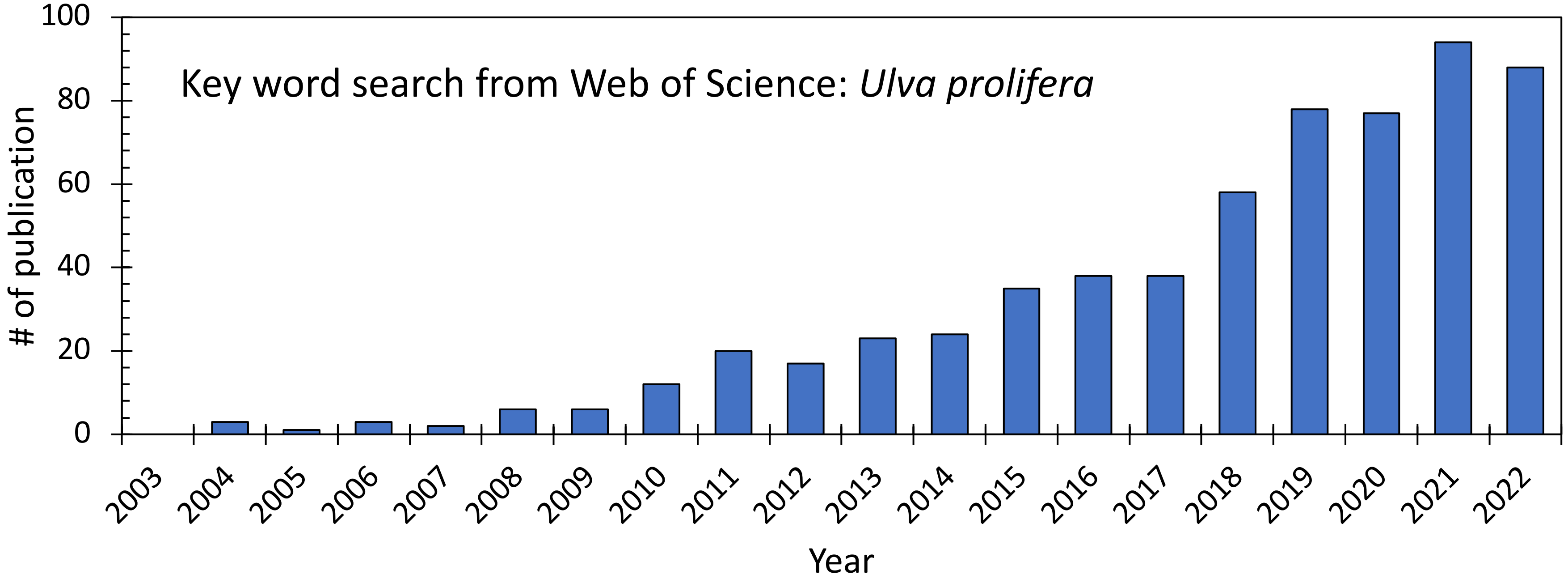
Zhang et al., (2019)

Golden tide

1. Background – what are the problems?

Despite the increased # of studies, many questions remain unanswered:

1) **When, where, how often, trends?**
2) **Why?**
3) **Future trends?**

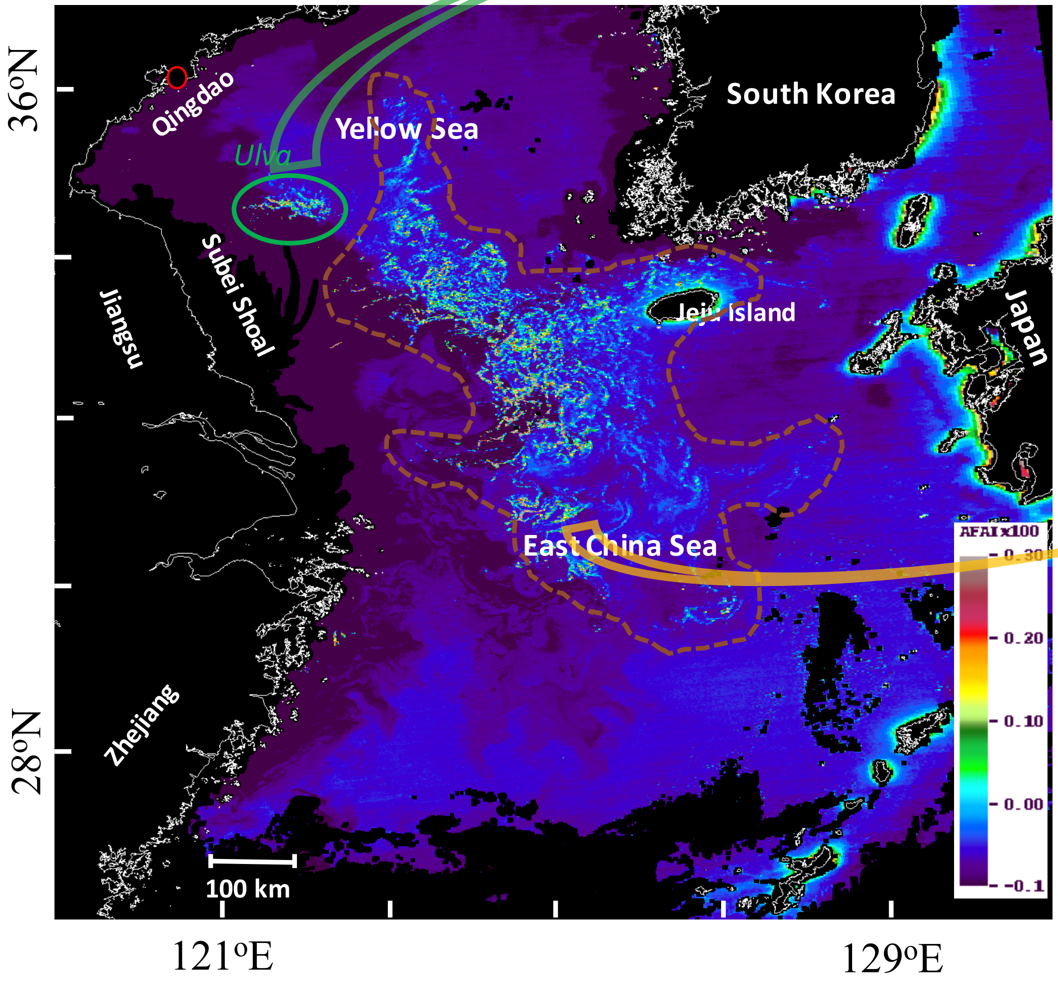


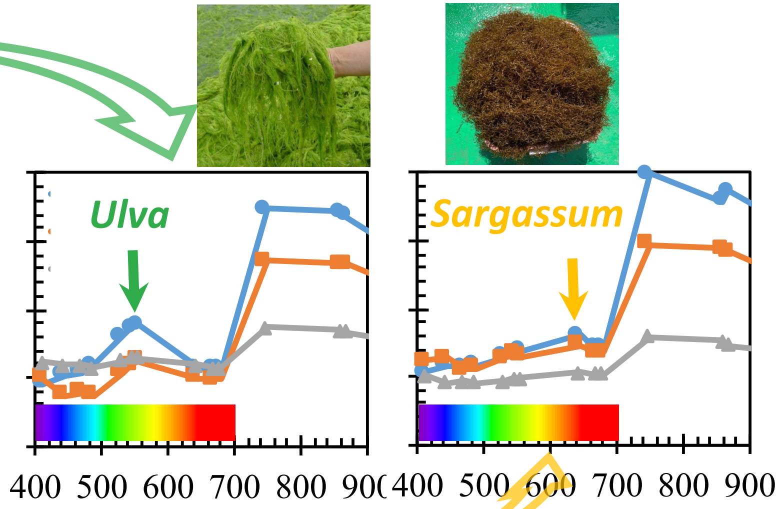
- I will address these questions using remote sensing and other data.

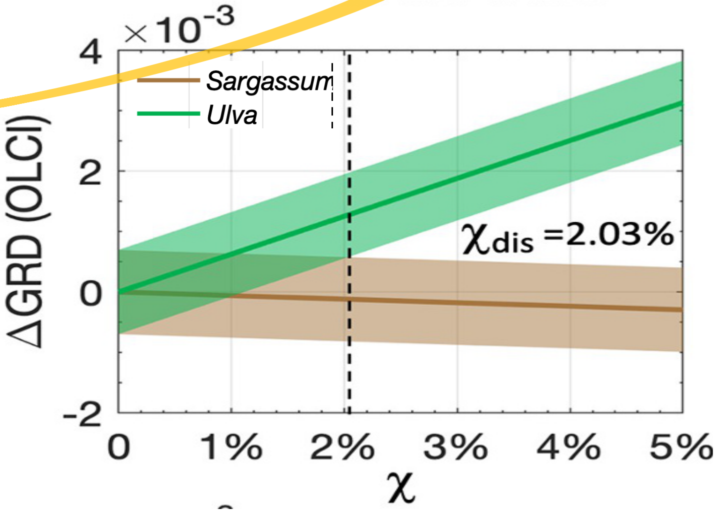
2. Methodology – how (1)?

Step 1: Spatial anomaly in AFAI image

Step 2: Spectral shape classification







(Qi et al., 2017
Qi and Hu, 2021)

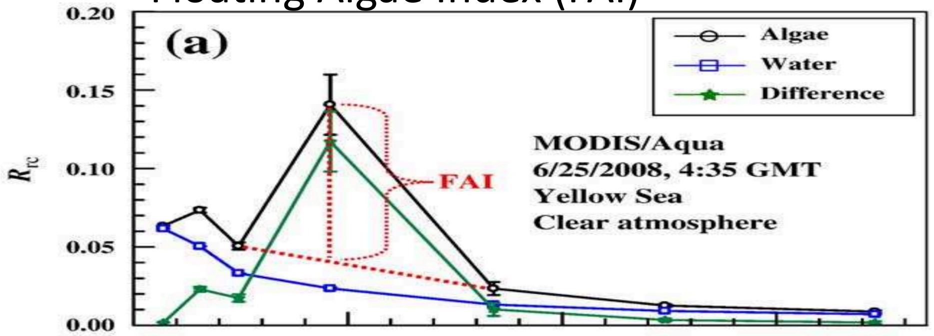
2. Methodology – how (2)?

Step 3: pixel unmixing

Each square is a 250-m pixel

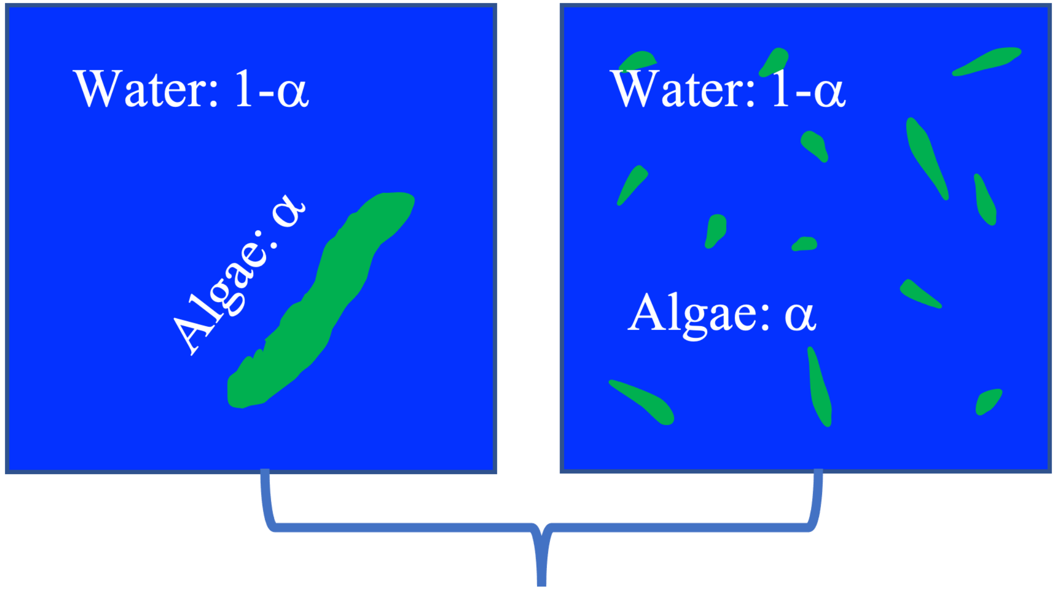
Hu et al. (2023)

Floating Algae Index (FAI)



Hu, (2009)

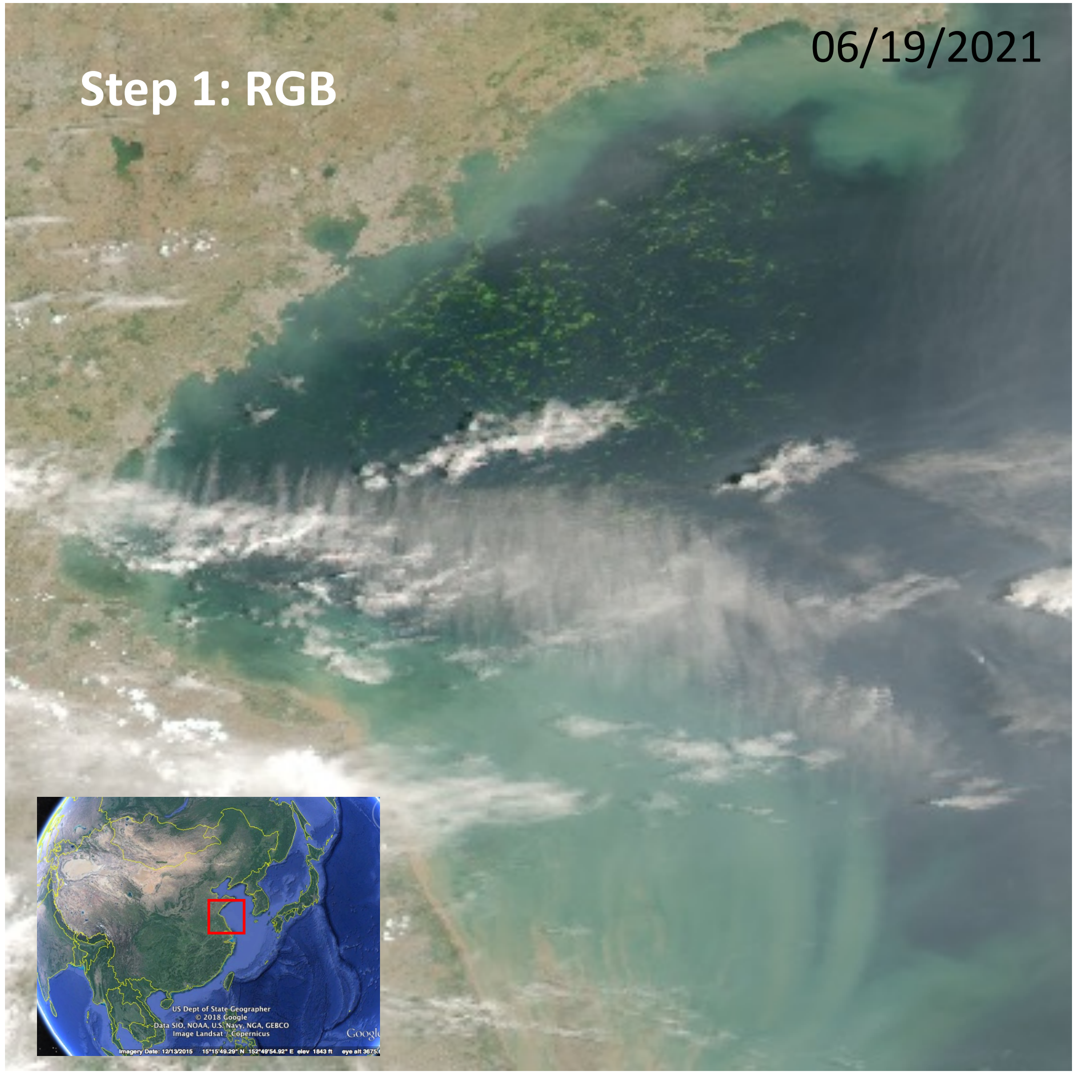
Target pixels

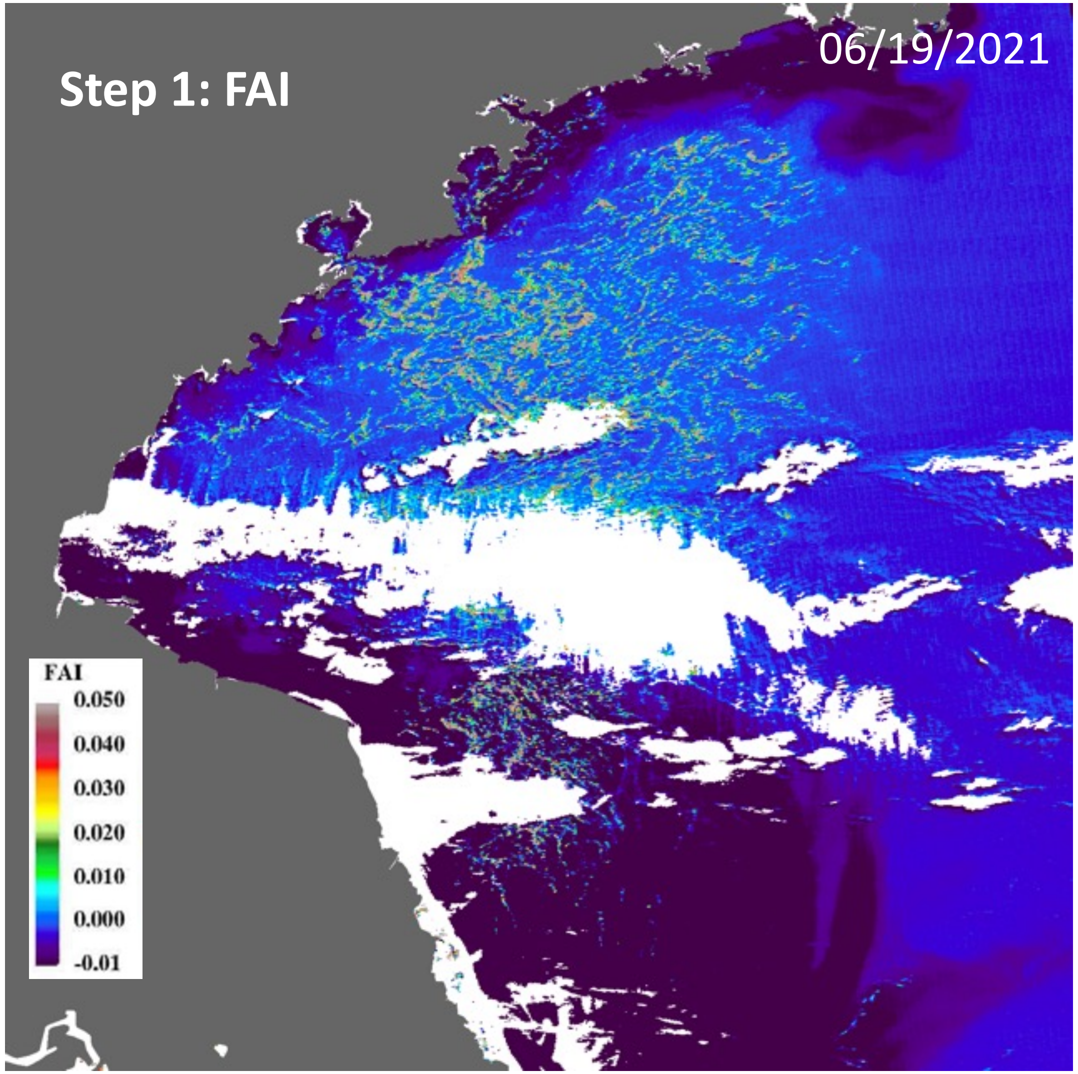


$$FAI_T = \alpha FAI_A + (1- \alpha)FAI_W$$

2. Methodology – how (3)?

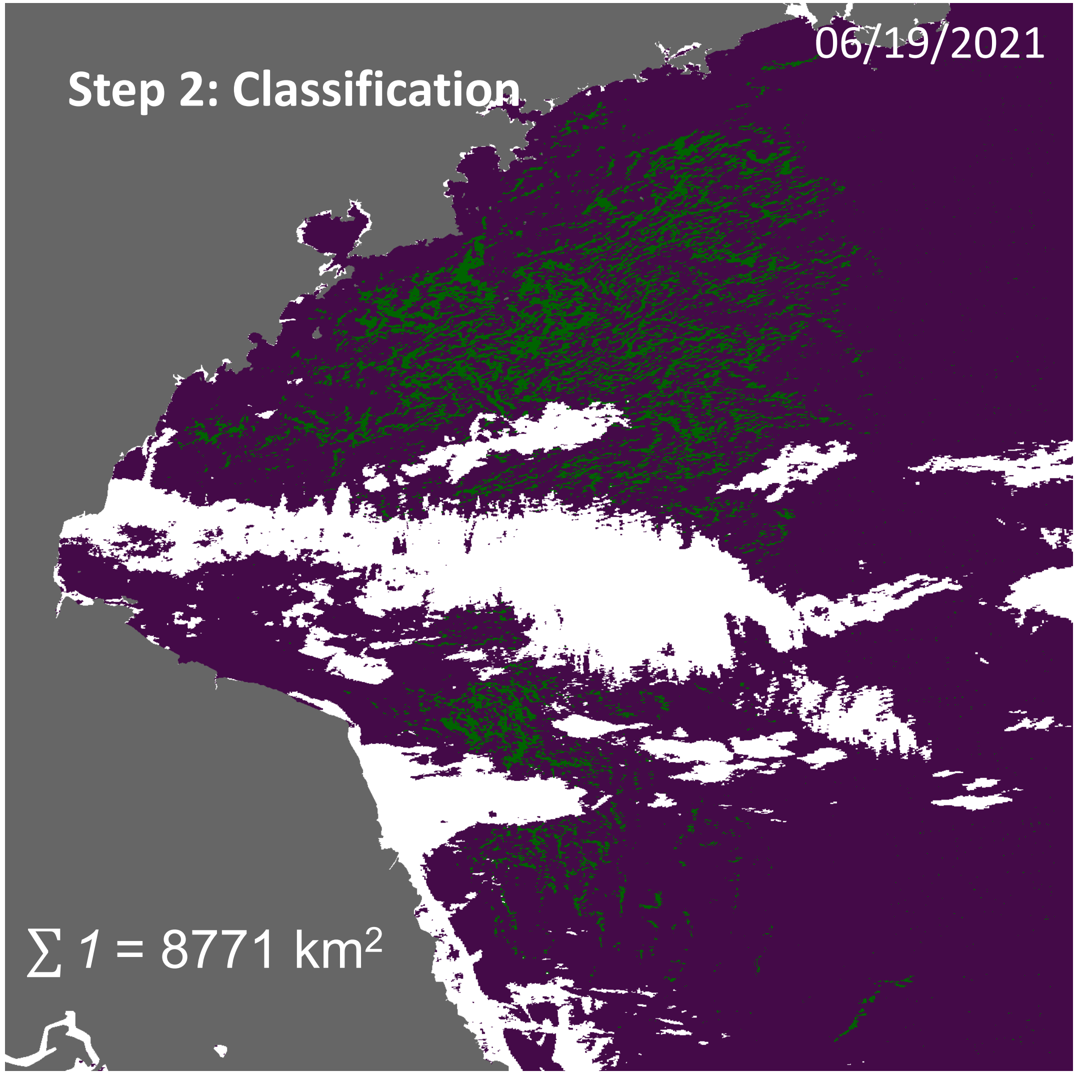
Examples: the *Ulva* case

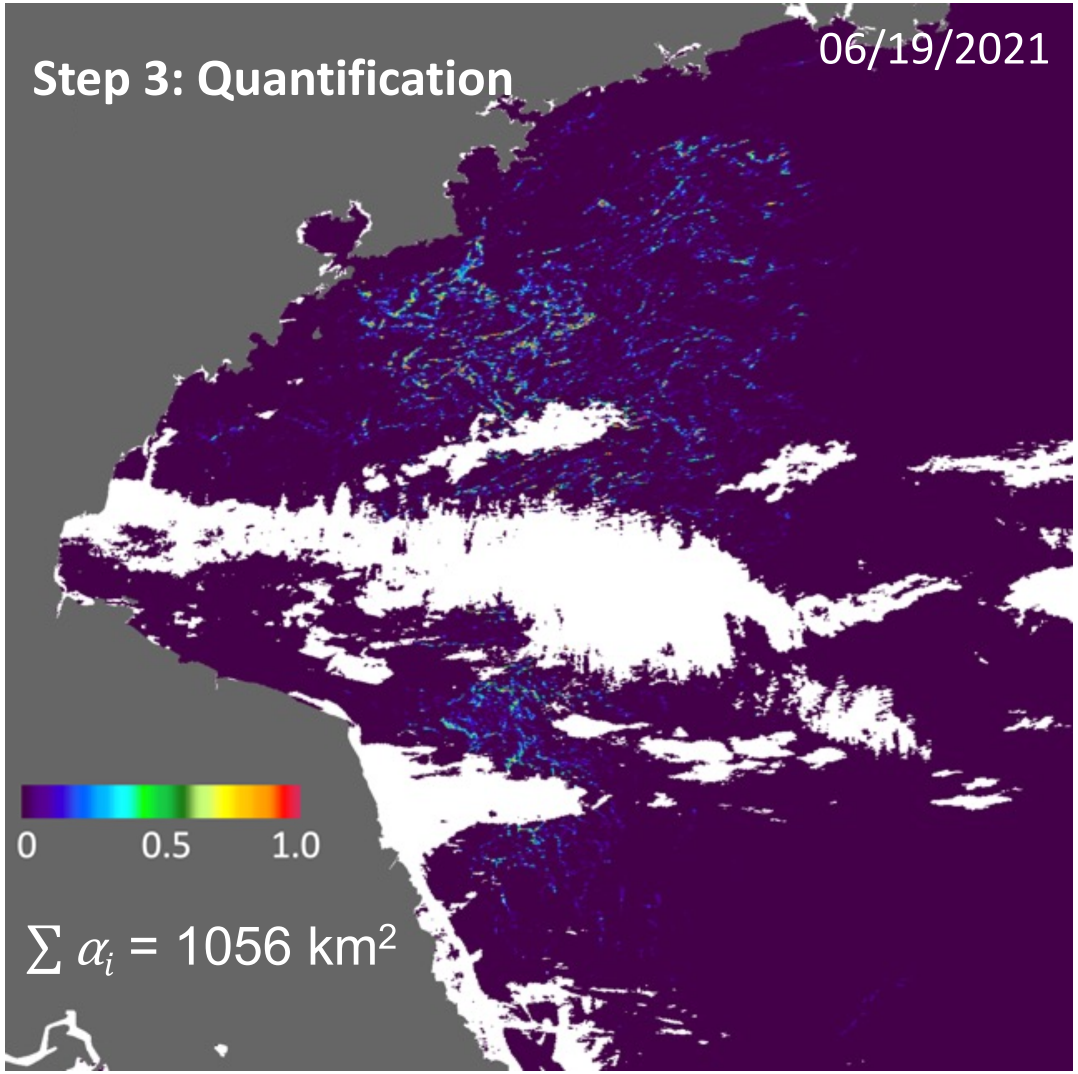




2. Methodology – how (4)?

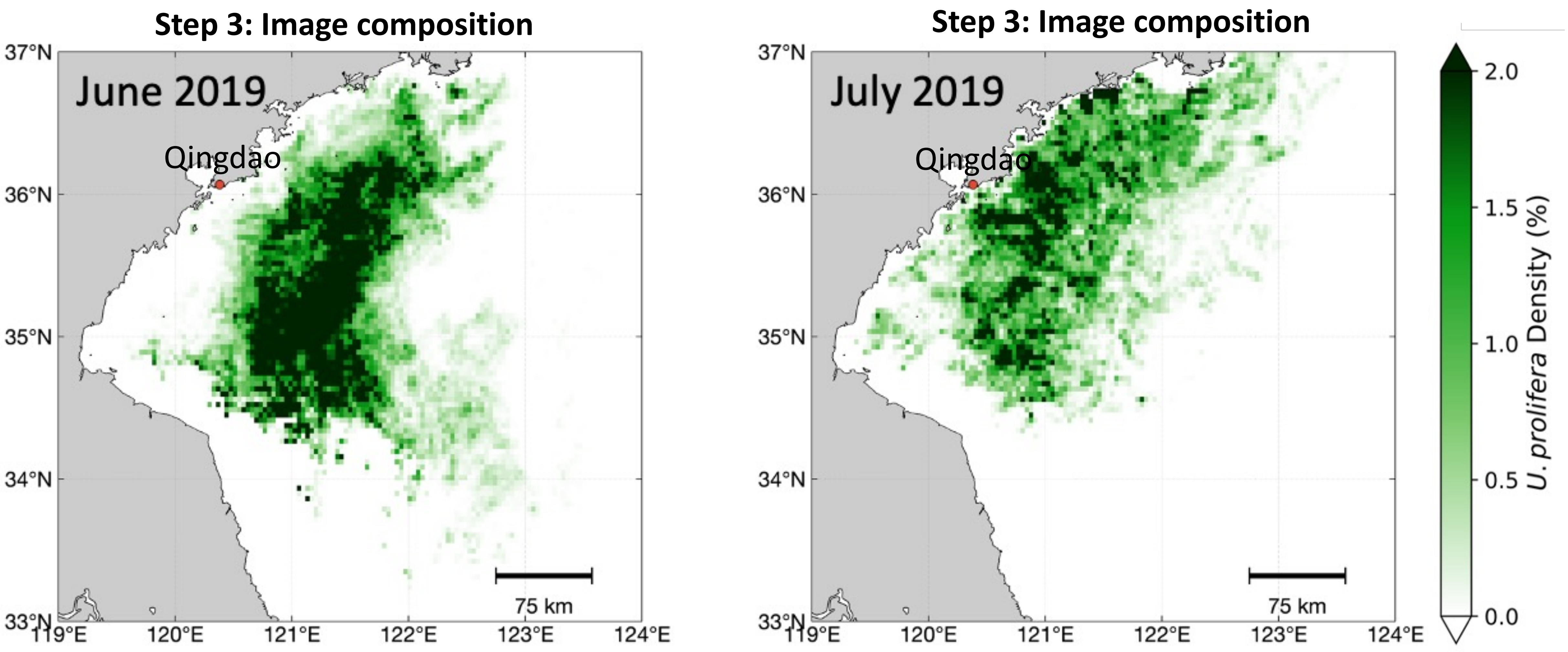
Examples: the *Ulva* case





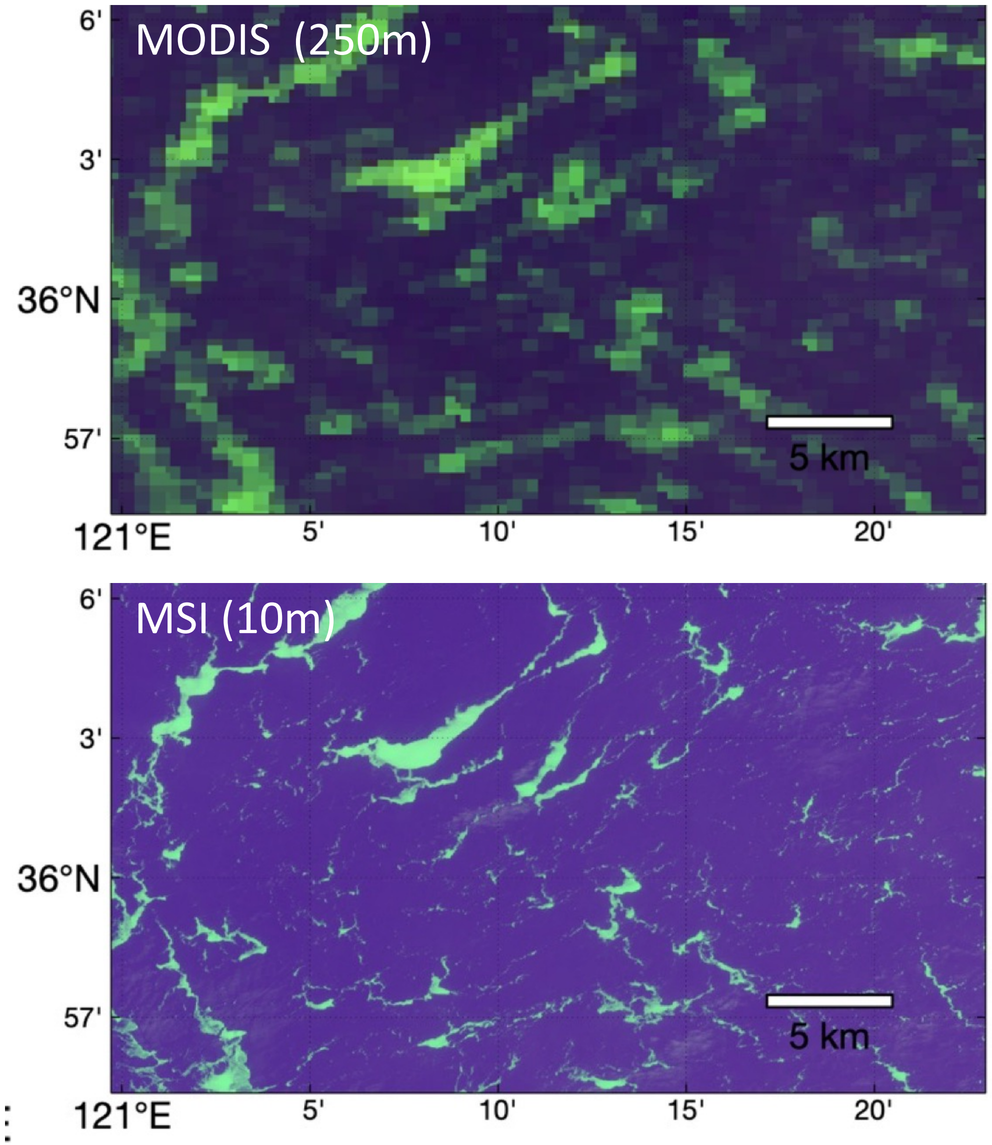
2. Methodology – how (5)?

Examples: the *Ulva* case

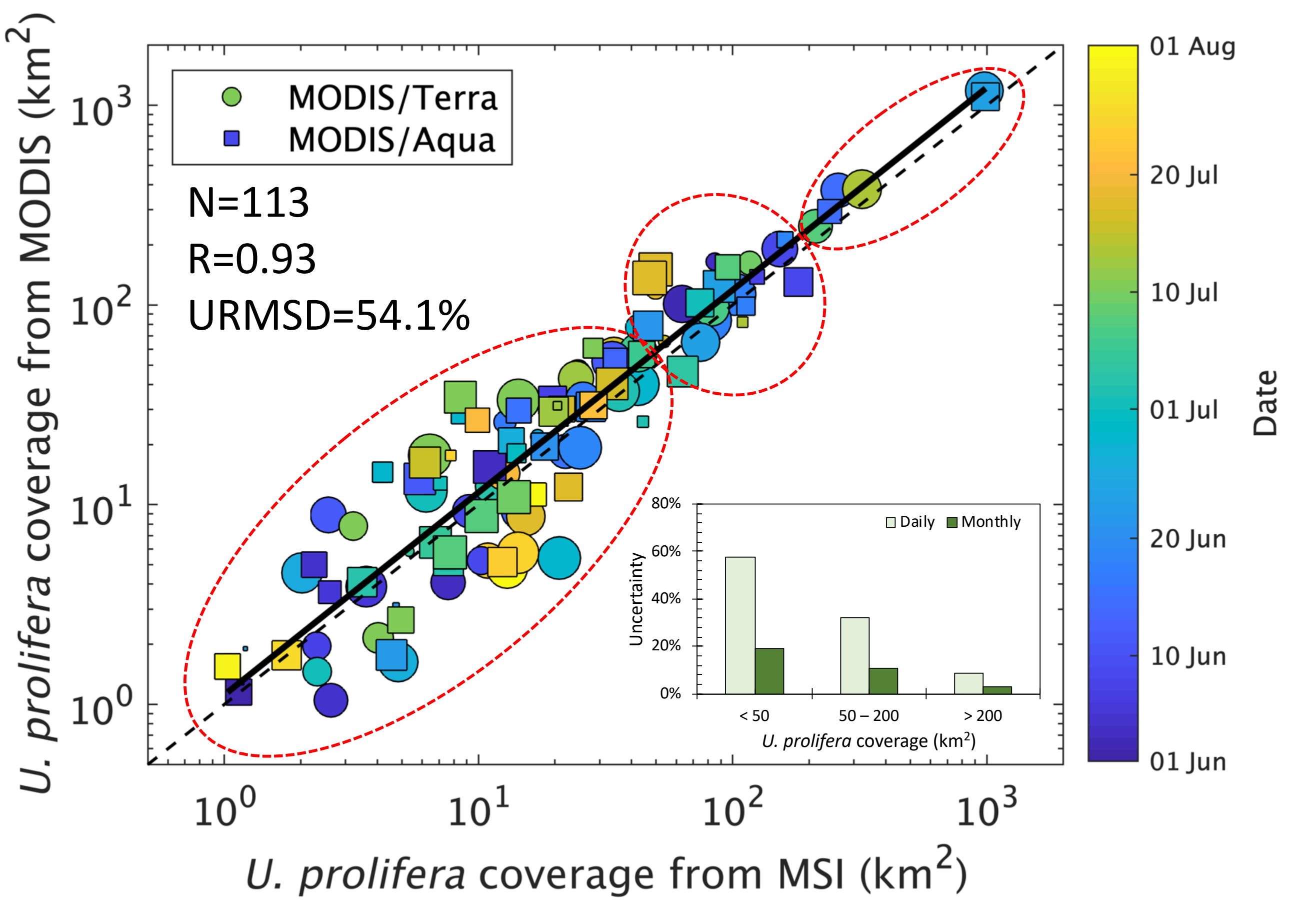


2. Methodology – how (6)?

How much can we trust these results?



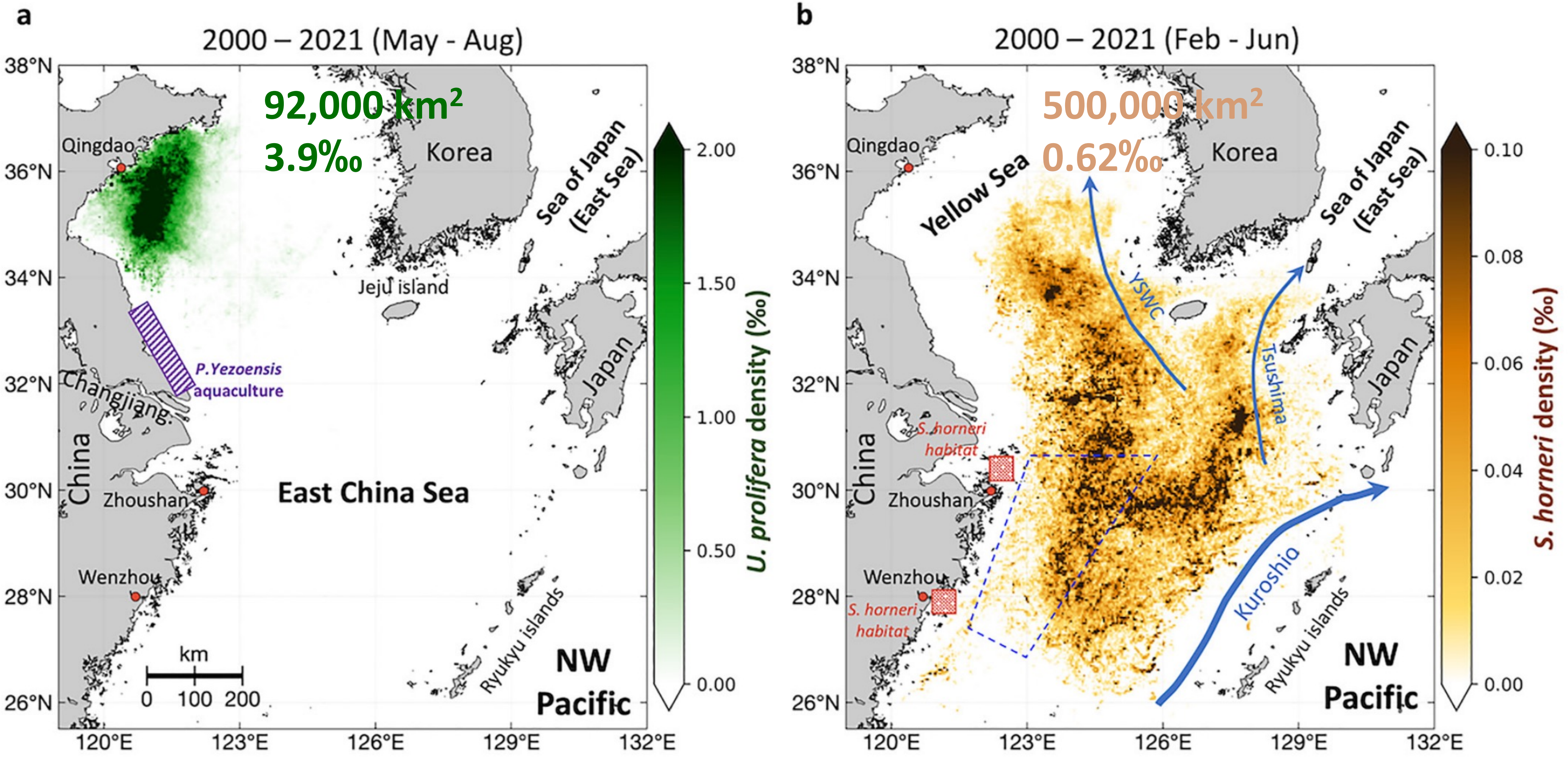
Understanding uncertainties using high-resolution imagery



Qi et al. (2023)

3. Findings – where, when, and how much (1)?

Cumulative footprint and mean density

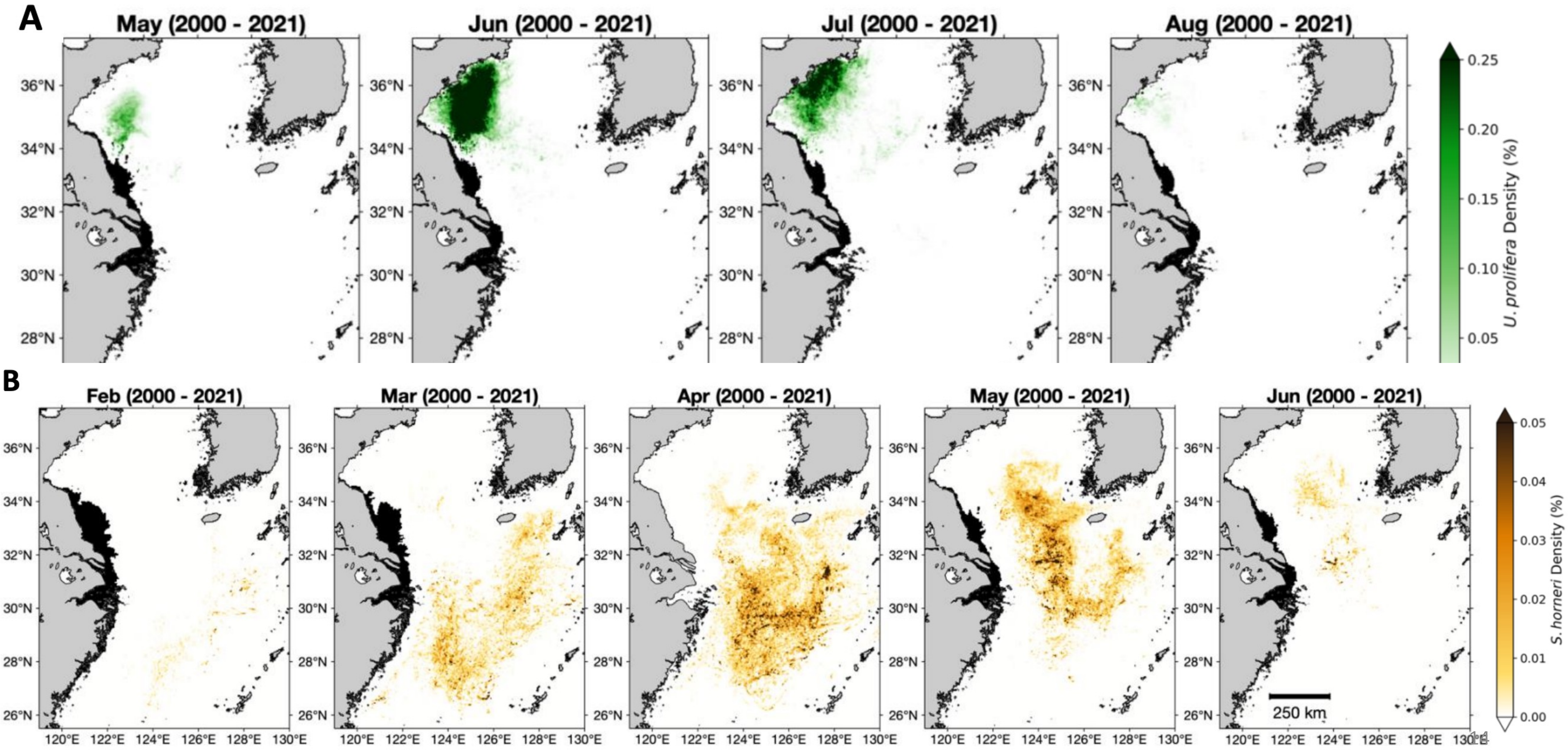


Qi et al. (2022, GRL)

3. Findings – where, when, and how much (2)?

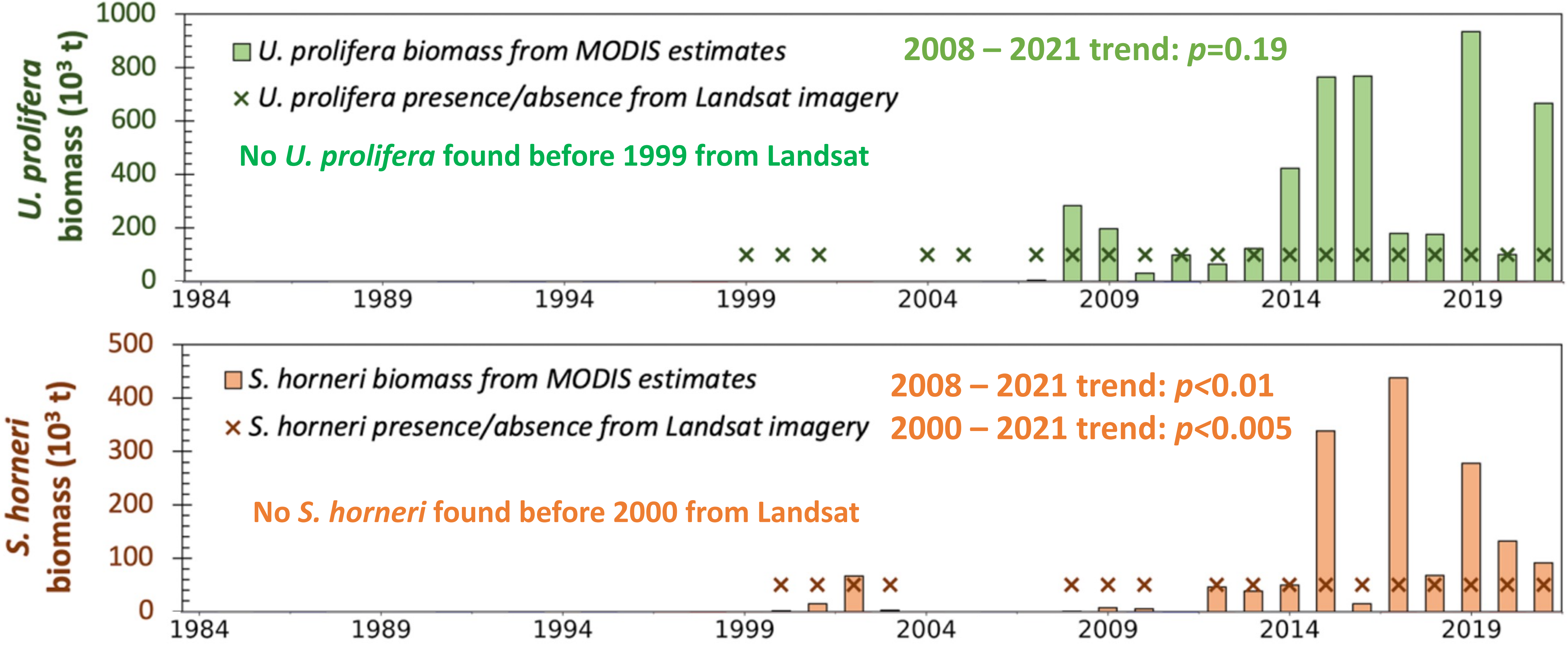
Strong seasonality

Qi et al. (2022, GRL)



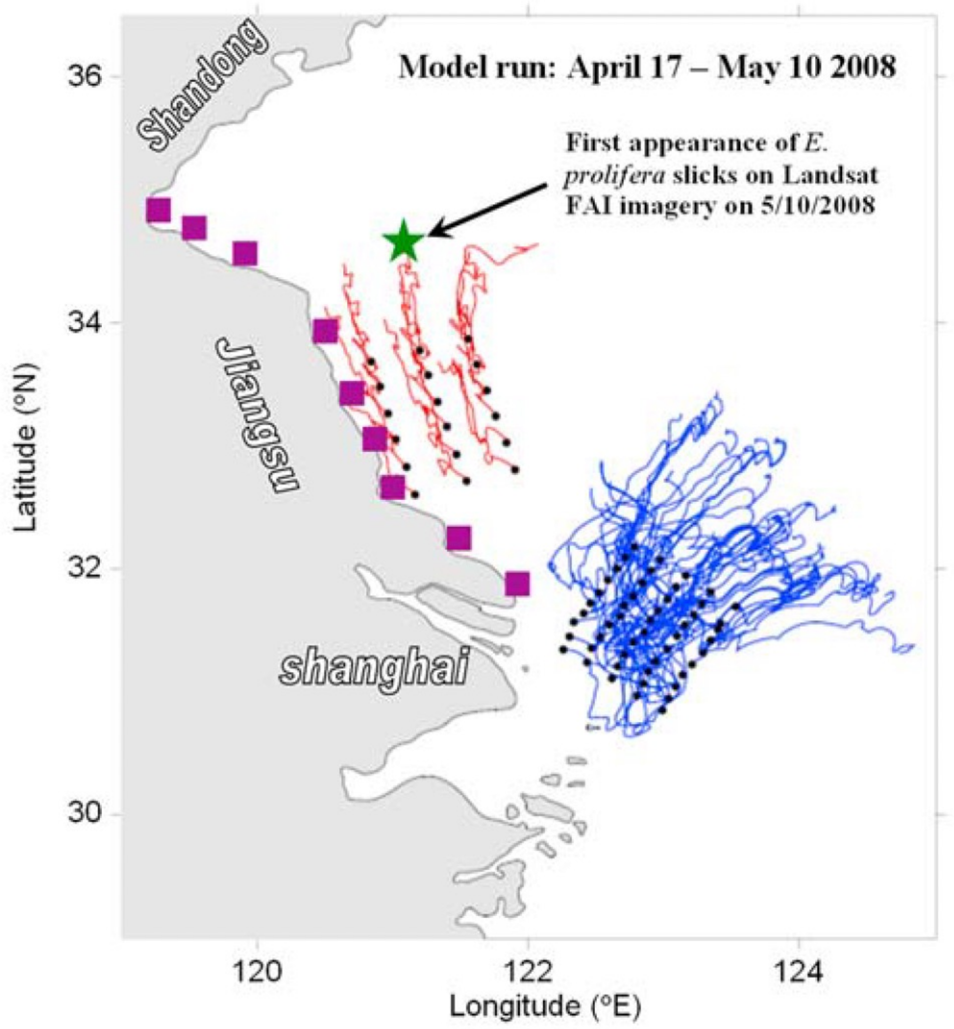
3. Findings – where, when, and how much (3)?

Interannual variability and long-term trends



3. Why – Origins (1)

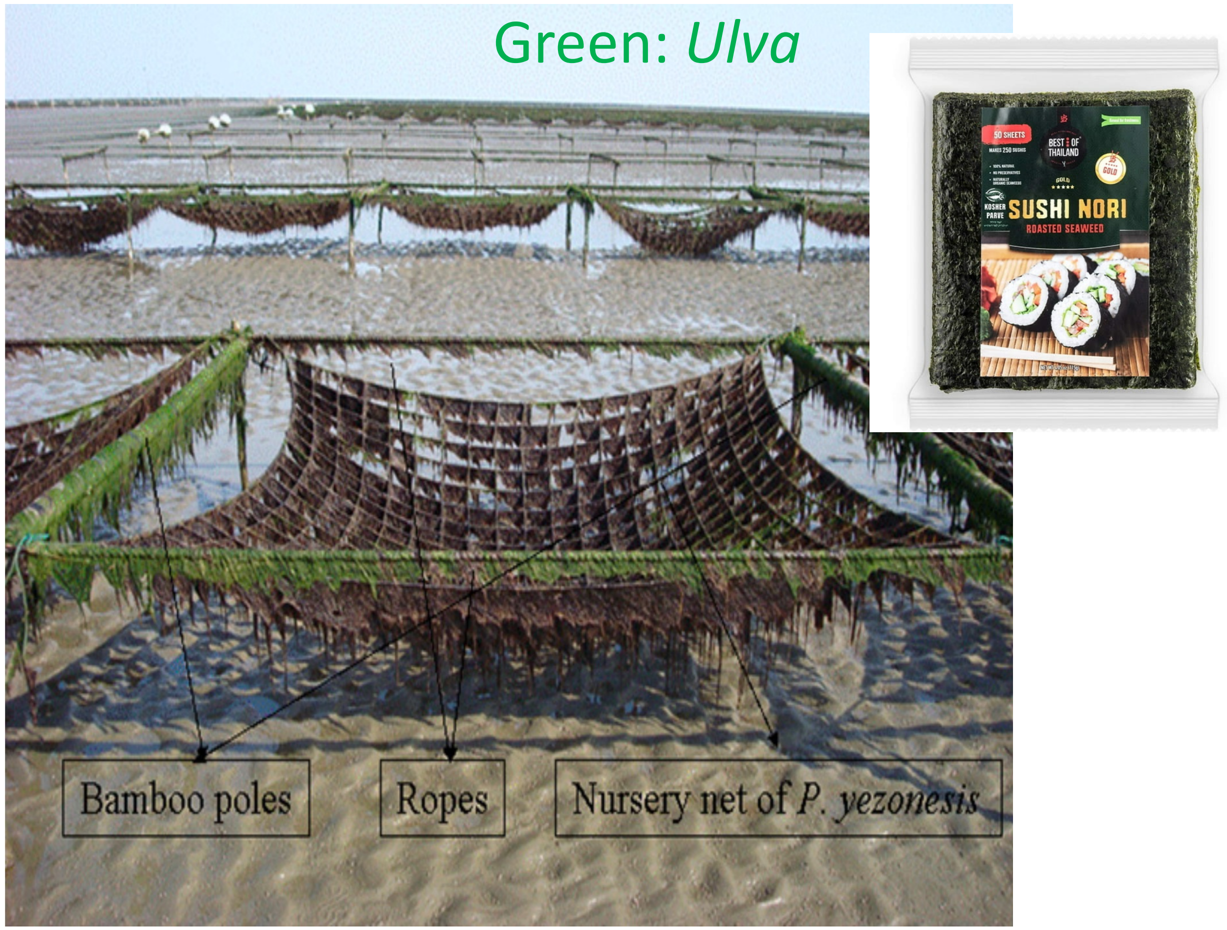
Ulva origin: Subei bank with increased *P. Yezoensis* aquaculture



Hu et al. (2010, JGR)

Brown: *P. Yezoensis* (Nori)

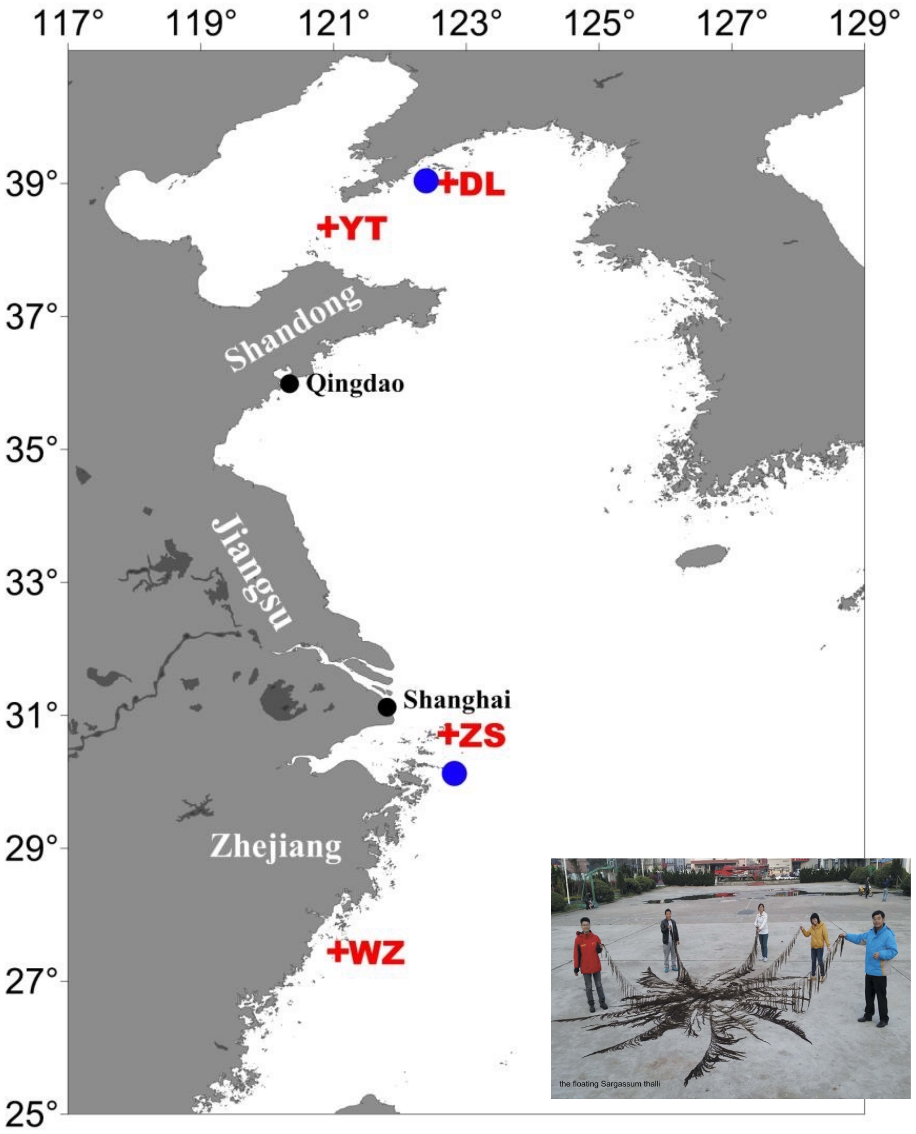
Green: *Ulva*



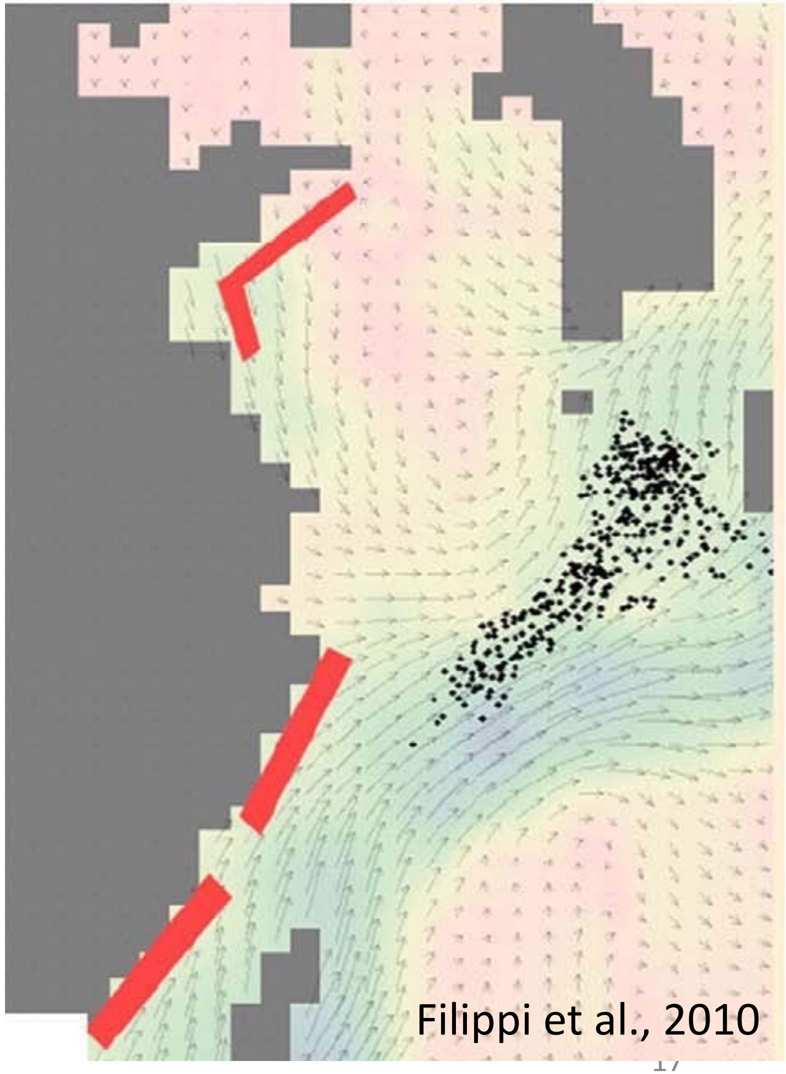
Liu et al. (2009, MPB)

3. Why – Origins (2)

Sargassum origin: multiple natural sources



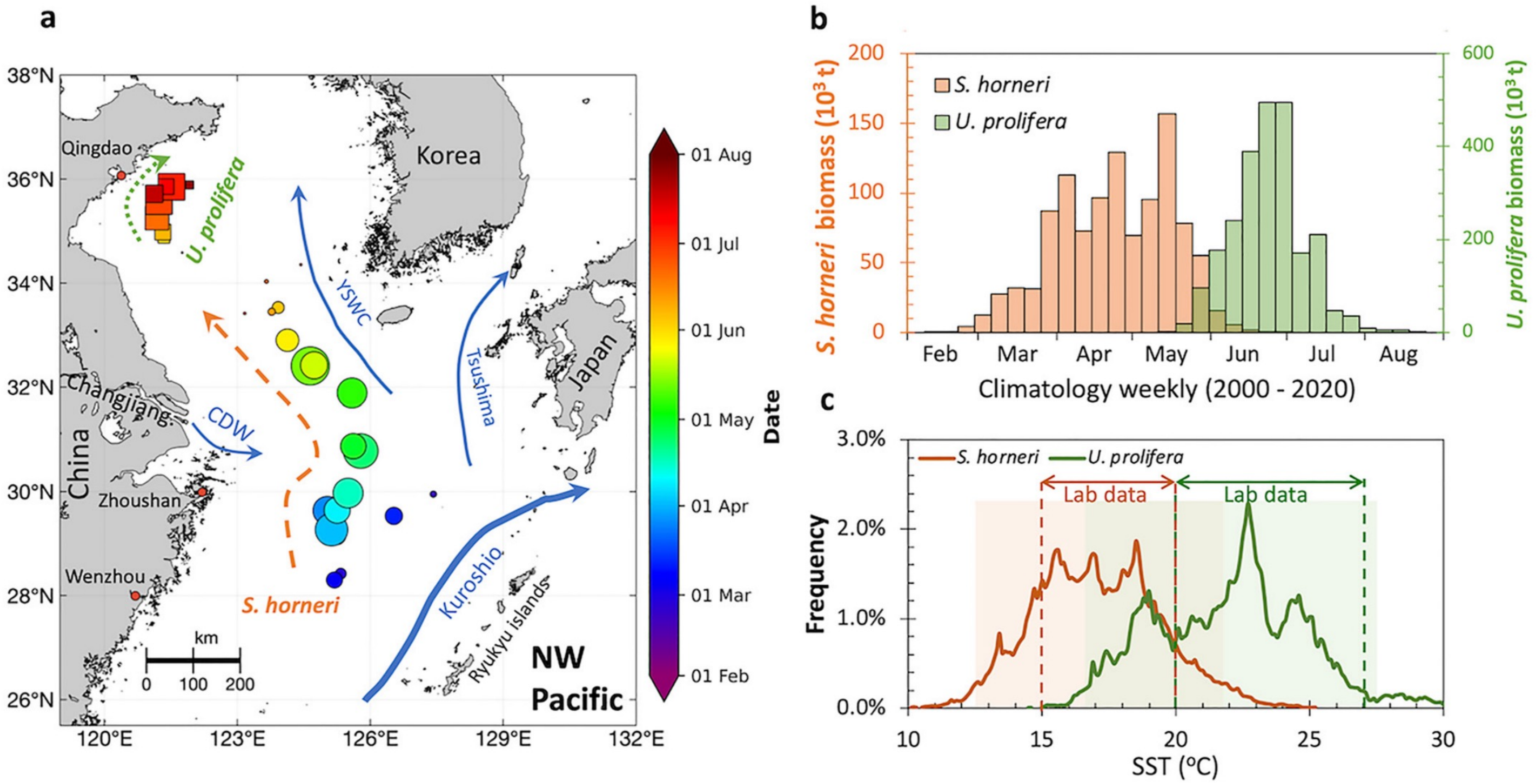
Xiao, 2019; Zhang et al., 2019



Filippi et al., 2010

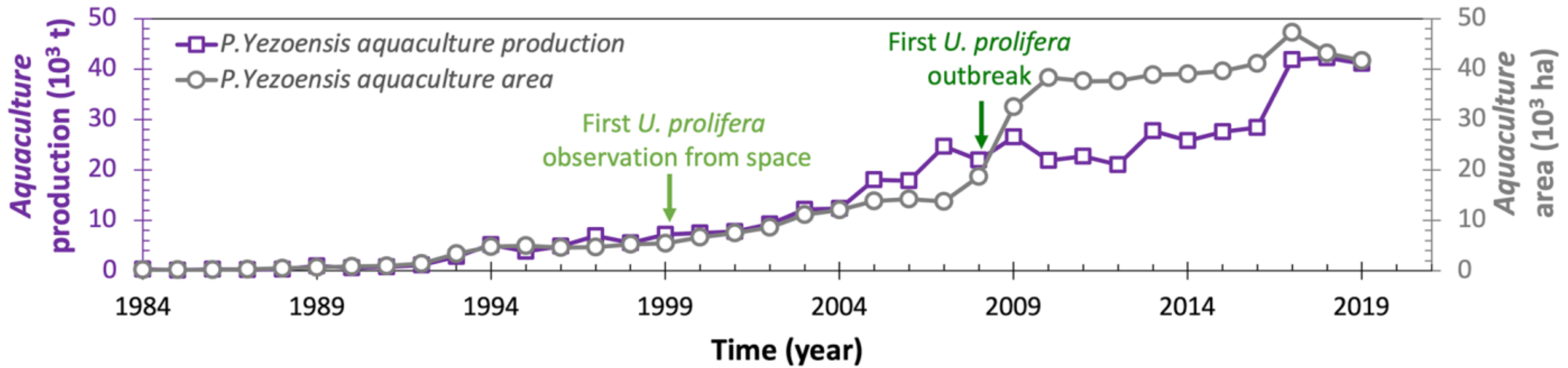
3. Why – Distributions and Seasonality

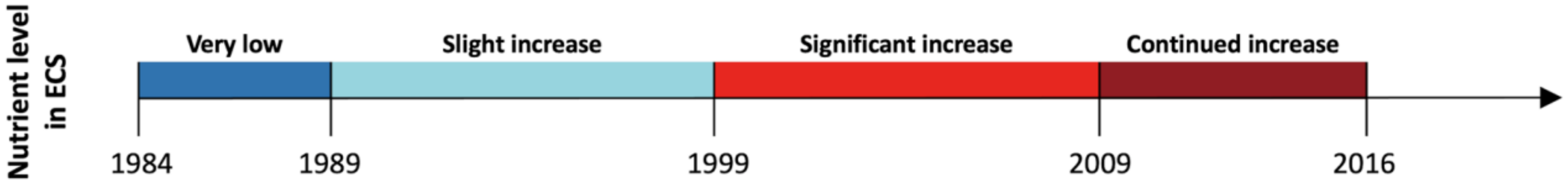
Distribution driven by ocean currents, winds, and temperature



3. Why – Long-term trends (1)

Chronic increases of aquculture and nutrients drive long-term trends – some tipping points?

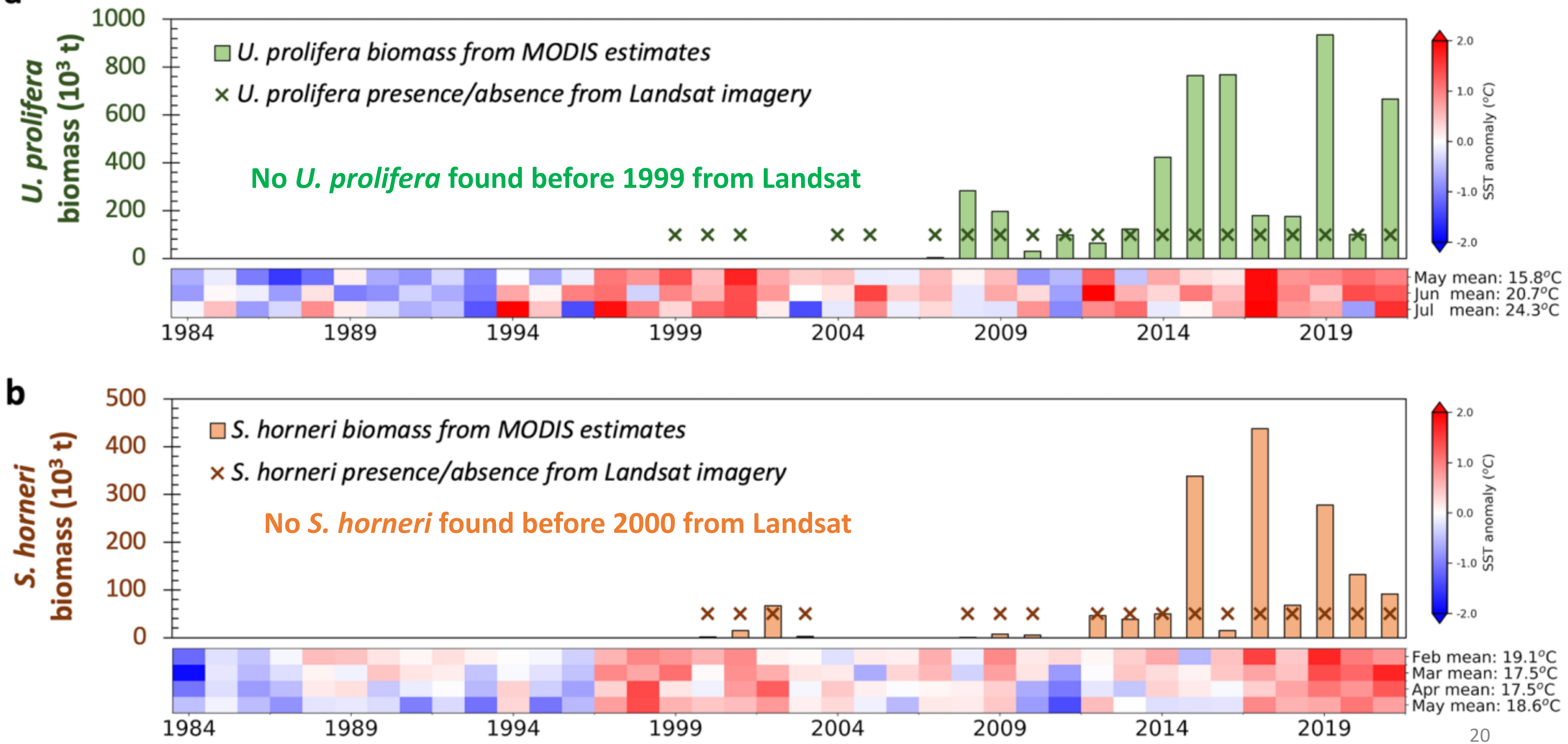




Qi et al. (2022, GRL)

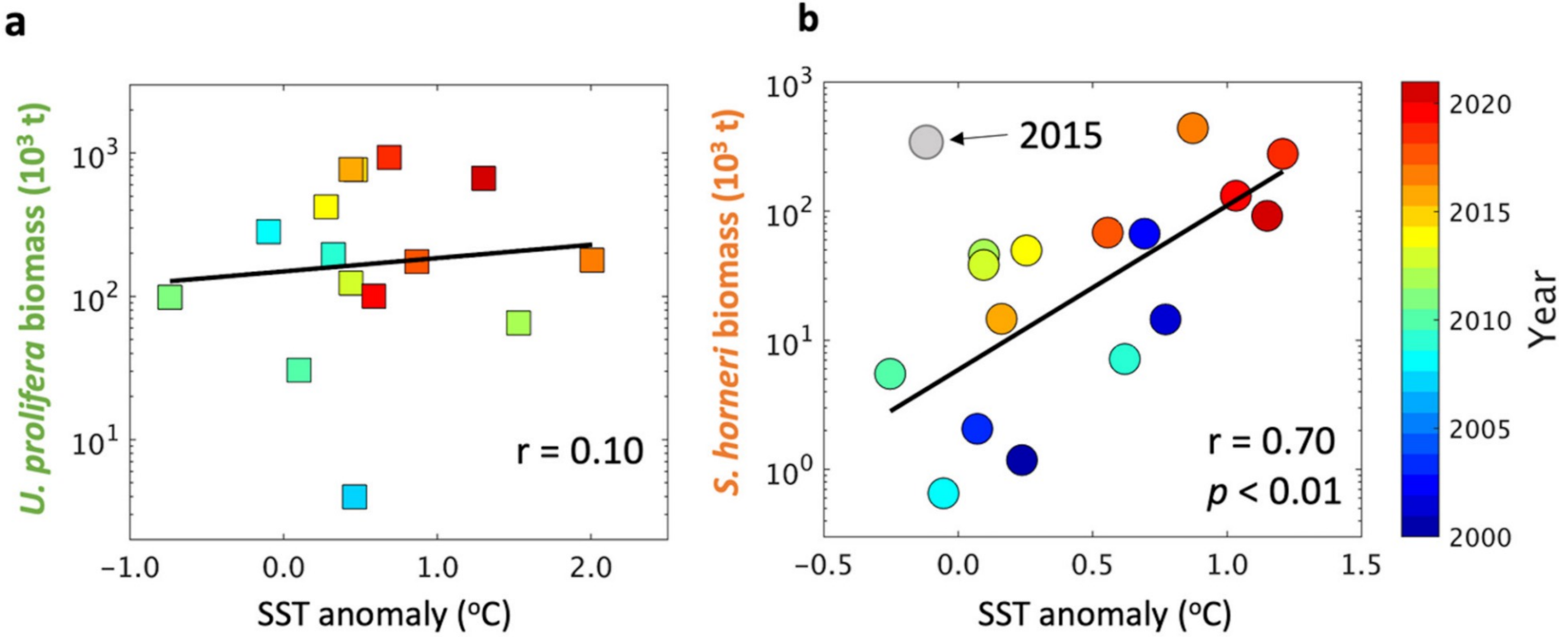
3. Why – Long-term trends (2)

Temperature controls of long-term trends and inter-annual variability?



3. Why – Long-term trends (3)

Temperature controls of long-term trends and inter-annual variability?

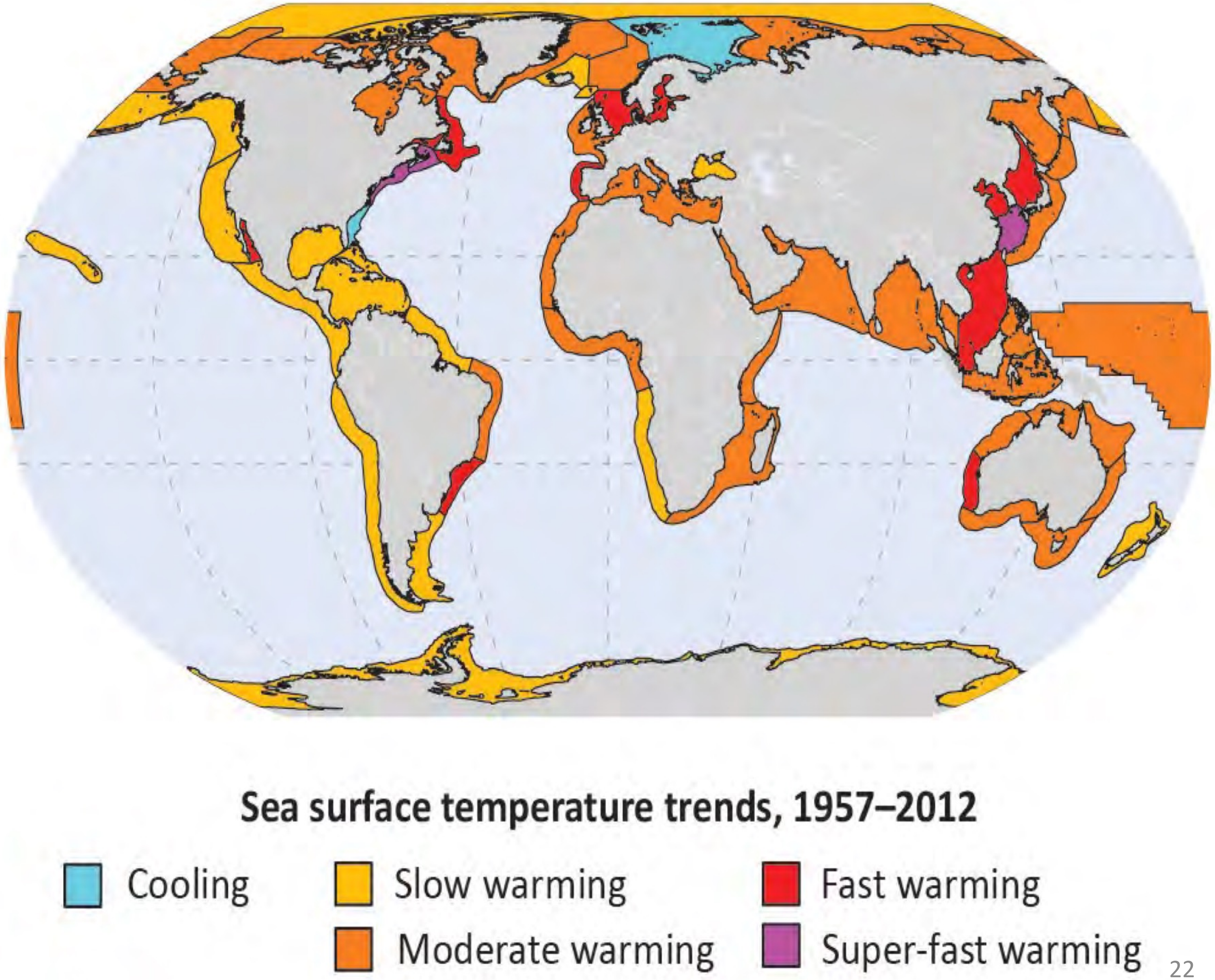


4. So what – future predictions?

Of 63 large marine ecosystems (LMEs), 3 showed "super-fast" warming (up to 1.6^{o}C).

One of these is the ECS.

Map from Igor Belkin (URI)



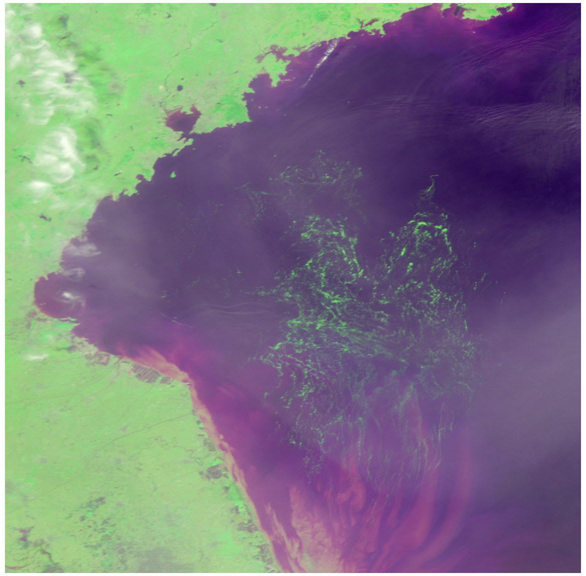
4. So what – carbon cycling and ocean ecology

- How do these seaweeds impact carbon cycling?
- How do they compete with phytoplankton for nutrients?
- How do they impact fisheries and other marine animals?
- Can they be used to make products such as fertilizers, animal food, etc?
- ……..

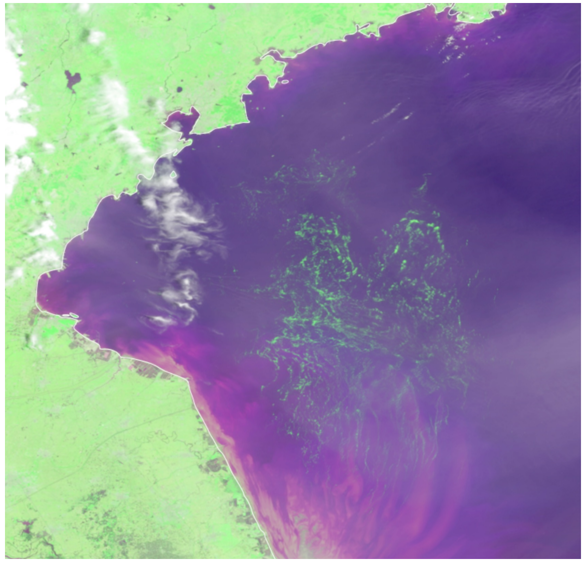
Monitoring and Tracking (1)

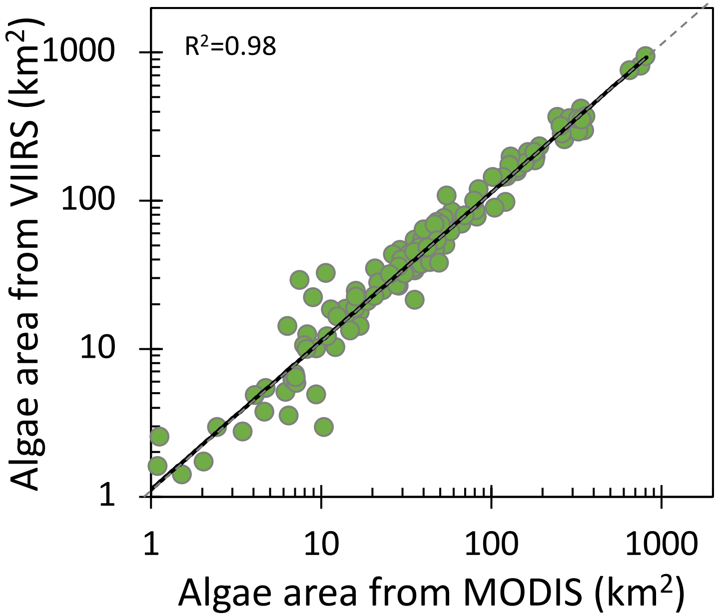
Multi-sensor for better coverage and continuity

MODIS/Aqua
6/6/2021



VIIRS/SNPP
6/6/2021

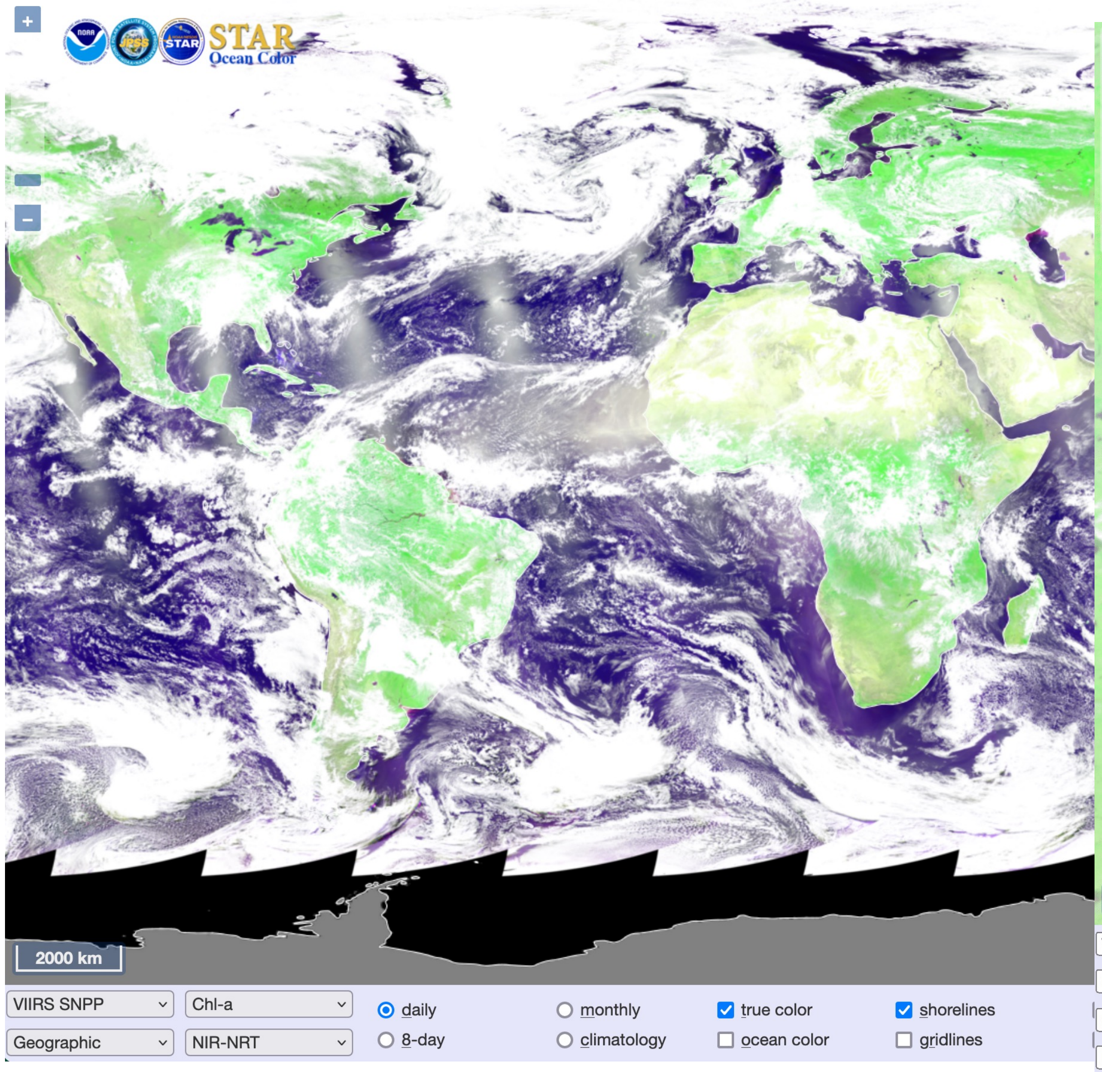


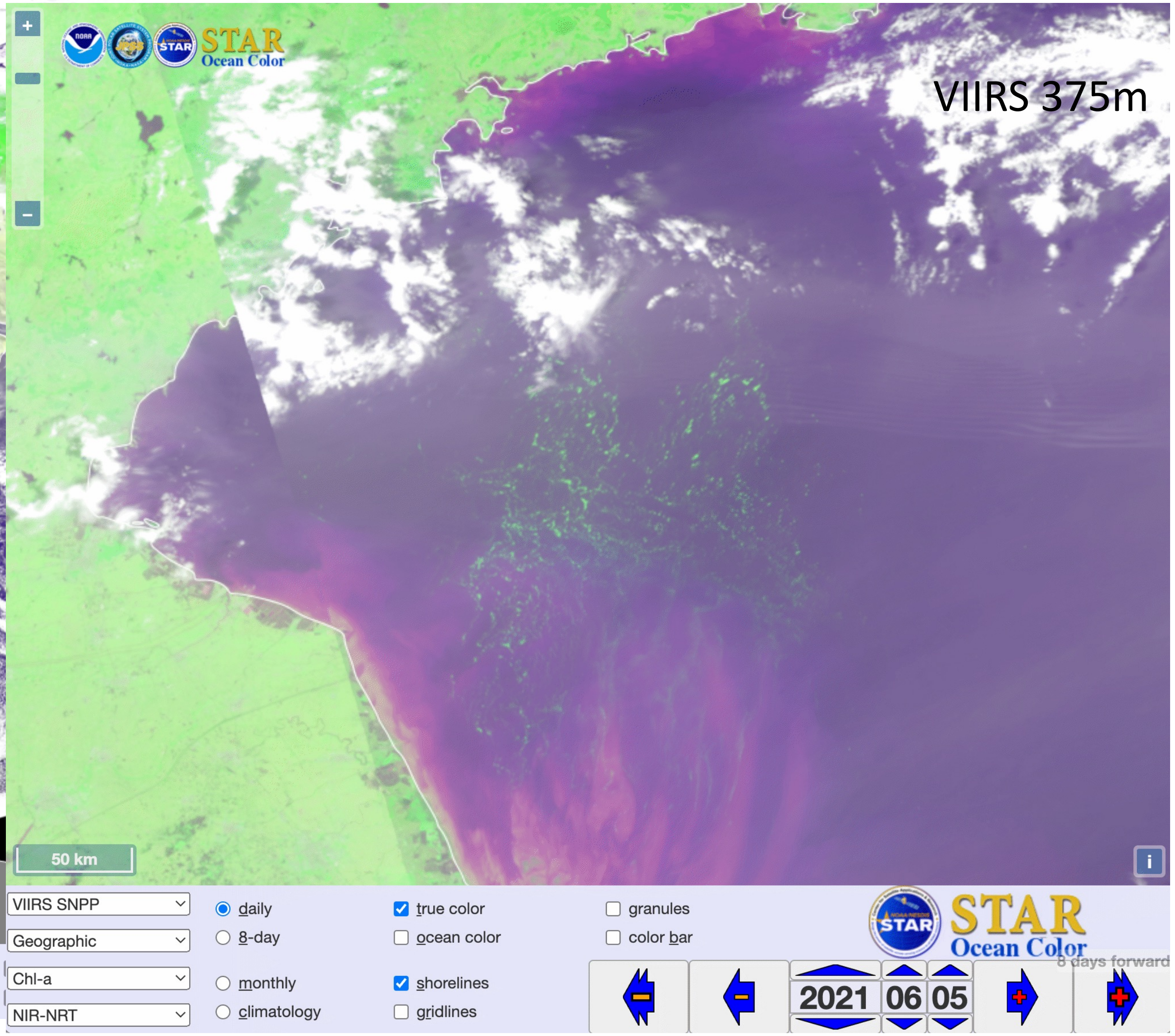


Monitoring and Tracking (2)

NOAA OCView provides real-time view of macroalgae and other floating matters

https://www.star.nesdis.noaa.gov/socd/mecb/color/ocview/ocview.html

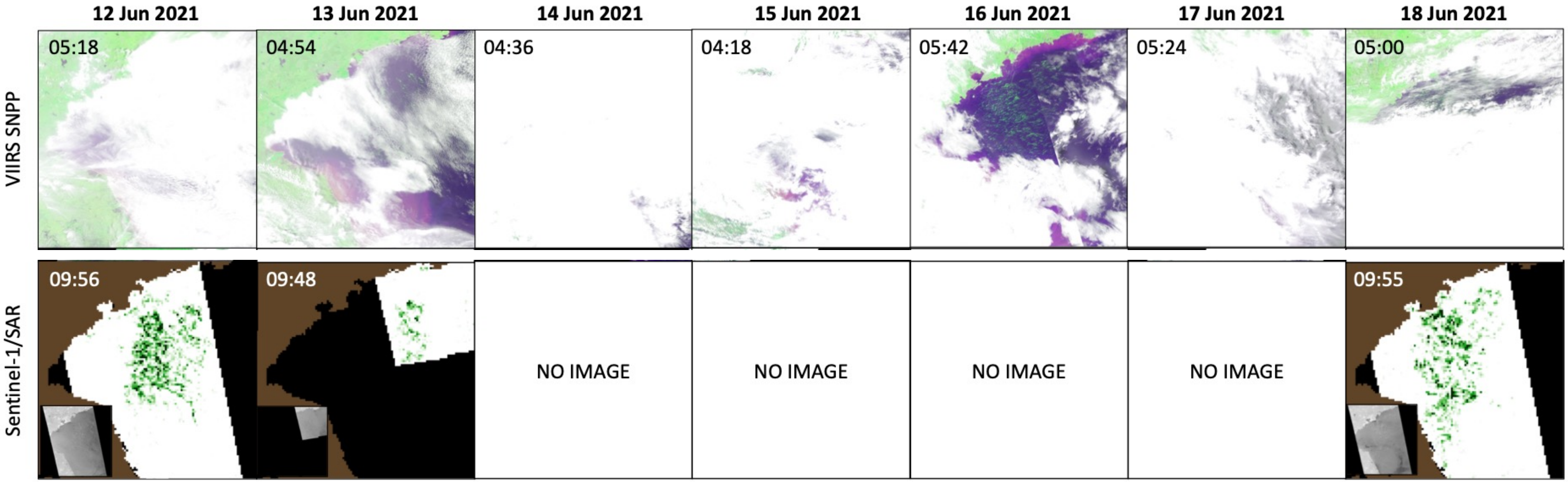




Mikelsons and Wang (2018, EOS)

Monitoring and Tracking (3)

Fill data gaps using SAR and other sensors



Qi et al. (2022, RSE)

Summary of findings

1. ***Ulva* cumulative footprint in the YS (92,000 km^2) << *Sargassum* in the ECS (500,000 km^2). *Ulva* density (3.9‰) >> *Sargassum* (0.62‰)**
2. **Spatial distributions driven by currents and winds, and seasonality driven partially by temperature**
3. ***Ulva* originated from Subei bank (rich in *Nori* aquaculture), while *Sargassum* may have multiple sources**
4. **Long-term trends of *Ulva* appear to be driven by aquaculture, eutrophication, and possibly temperature**

   Human controls: aquaculture, fertilizer use, mitigation efforts
5. **Long-term trends of *Sargassum* appear to be driven by temperature, and possibly by eutrophication**

   Climate controls: Ocean warming provided optimal temperature range for algae growth

Conclusions

1. **Technology - Multi-sensor remote sensing is powerful in both analysis and near rea-time monitoring**
2. **Science – Both *Ulva* and *Sargassum* are projected to expand in future years under global warming, and more research is required to understand, predict, and manage these blooms.**

Thank you!

Questions and comments to Lin Qi (lin.qi@noaa.gov)

NOAA STAR Ocean Color Science Team