Modelling and theoretical perspectives on diazotrophs (with some discussion about *Trichodesmium*)

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What I won't be talking about:

- Detecting *Trichodesmium* from Space

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- Detecting *Trichodesmium* from Space

What I will be talking about:

- What do models and theory suggest about diazotroph biogeography?
- Why it is difficult to validate this biogeography?
  (i.e. why it would be very nice to detect diazotrophs from space)
- What is the biogeography of *Trichodesmium*?
  (I don't have an answer)

- What do I mean by “model”?

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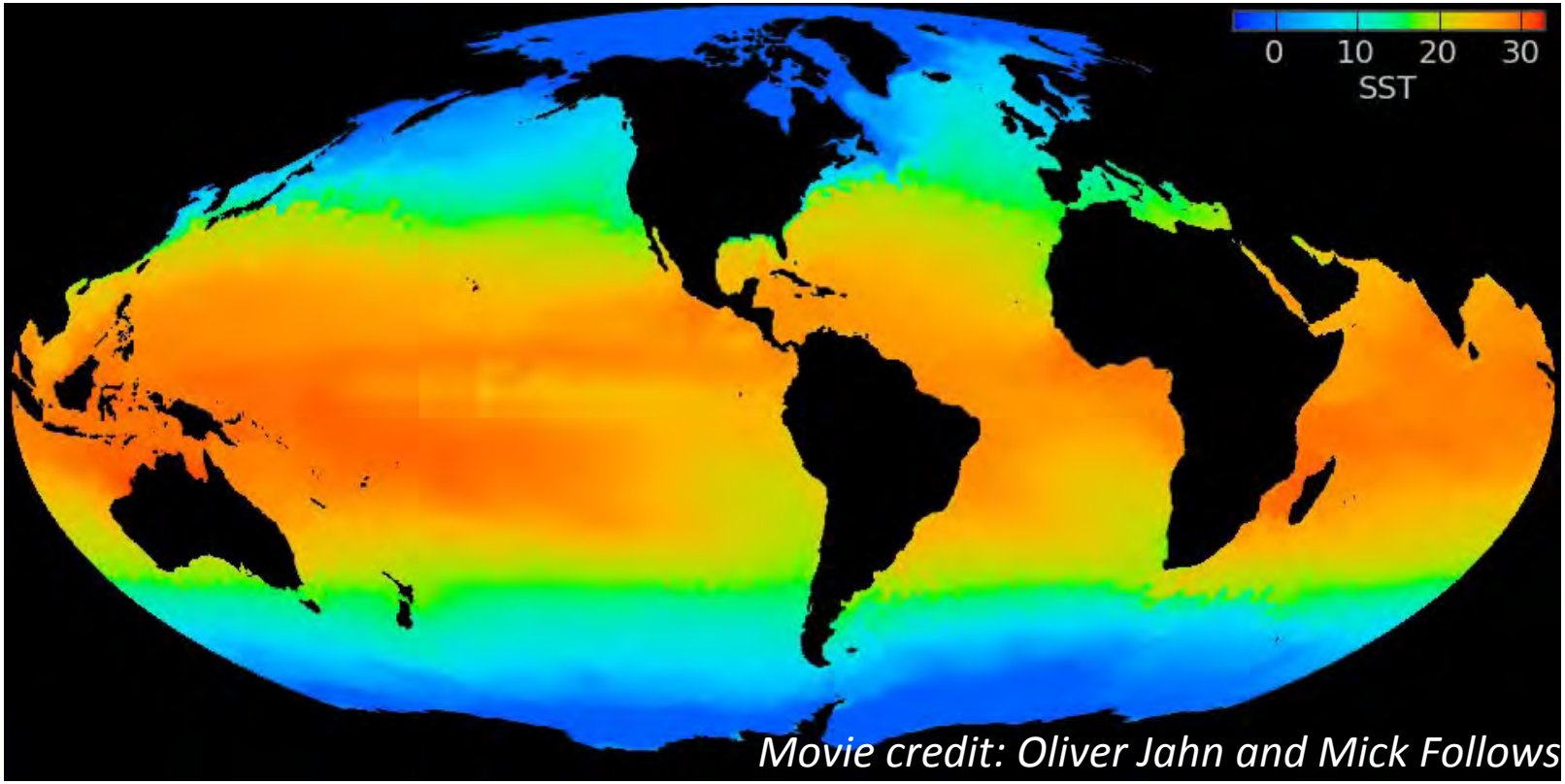
Physics: e.g velocity, mixing, temperature

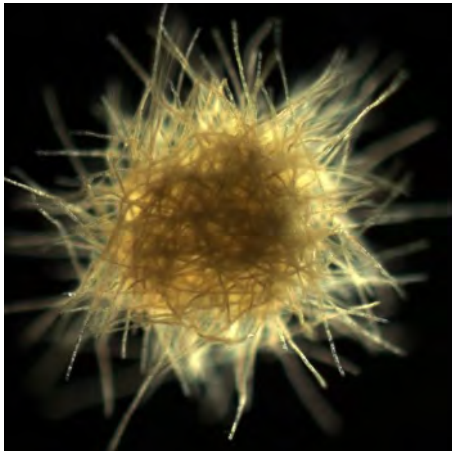
Biogeochemistry: e.g. Carbon, nutrients, DOM, POM

Ecosystem: e.g. Phytoplankton (C, Chl), zooplankton



Movie credit: Oliver Jahn and Mick Follows

- What are the traits and trade-offs of diazotrophs?
  (assumptions we need to model them)



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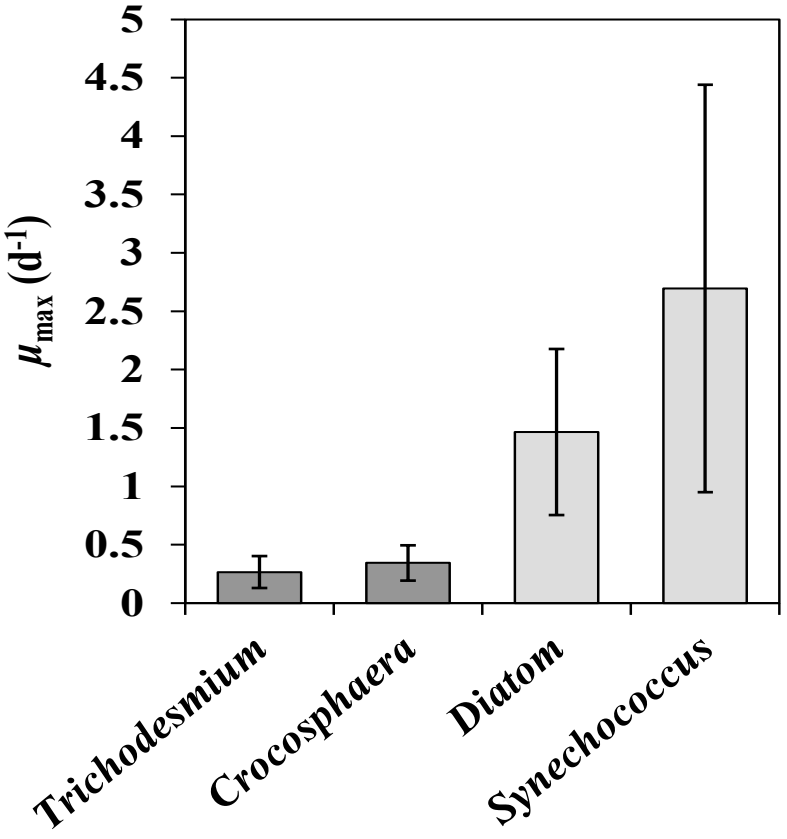

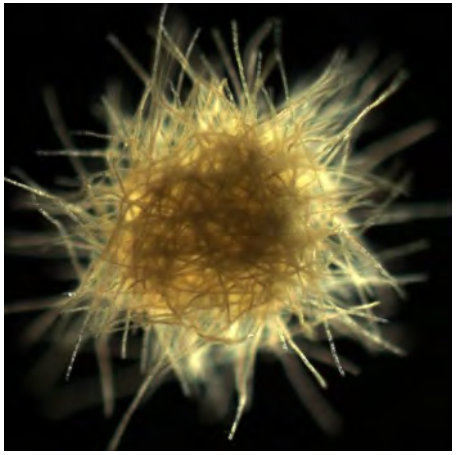

- slow growth rate

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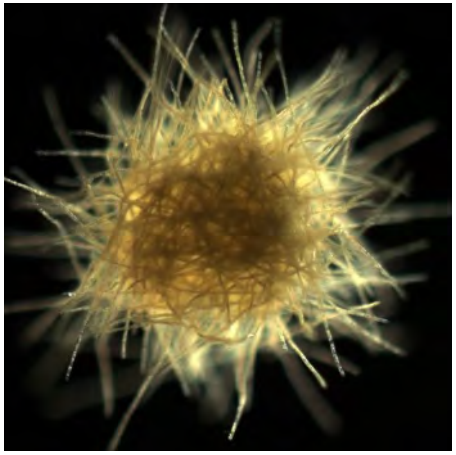

- slow growth rate
- but not nitrogen limited

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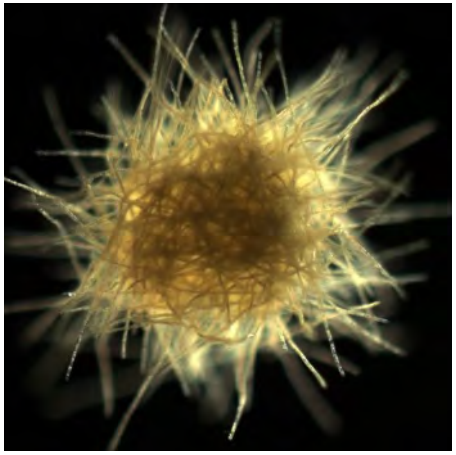
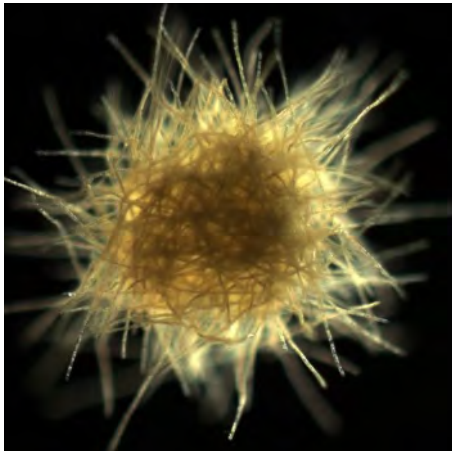


- slow growth rate
- but not nitrogen limited
- high iron requirements

- What do the traits/trade-offs mean for their biogeography?

Resource Ratio Theory:



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Tilman (1982), Dutkiewicz et al (GBC, 2012, BG, 2014), Ward et al (L+O, 2013)

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Resource Ratio Theory:

$$\frac{dP}{dt} = \mu_{oP} \min\left[\frac{N}{N+K_{N,P}}, \frac{Fe}{Fe+K_{Fe,D}}\right]P - m_P P$$

N or Fe-limited phyto

$$\frac{dD}{dt} = \mu_{oD} \frac{Fe}{Fe+K_{Fe,D}} D - m_D D$$

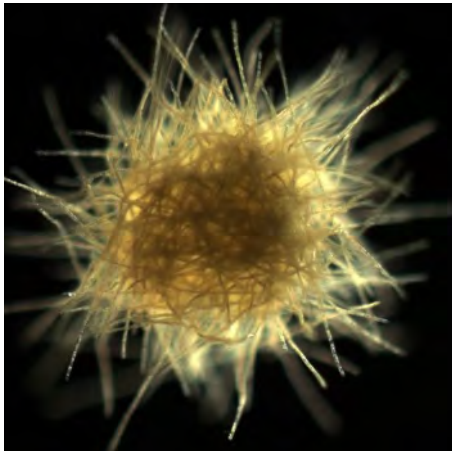
Fe-limited diazo

$$\frac{dN}{dt} = -\mu_{oP} \min\left[\frac{N}{N+K_{N,P}}, \frac{Fe}{Fe+K_{Fe,D}}\right]P + S_N$$

Dissolved inorganic nitrogen, N

$$\frac{dFe}{dt} = -R^P_{Fe:N}\mu_{oP} \min\left[\frac{N}{N+K_{N,P}}, \frac{Fe}{Fe+K_{Fe,P}}\right]P - R^D_{Fe:N}\mu_{oD}\frac{Fe}{Fe+K_{Fe,D}}D + S_{Fe}$$

Dissolved iron, Fe



$$\Phi_{Fe:N} = \frac{S_{Fe}}{S_N \; R^P_{Fe:N}}$$

- slow growth rate
- but not nitrogen limited

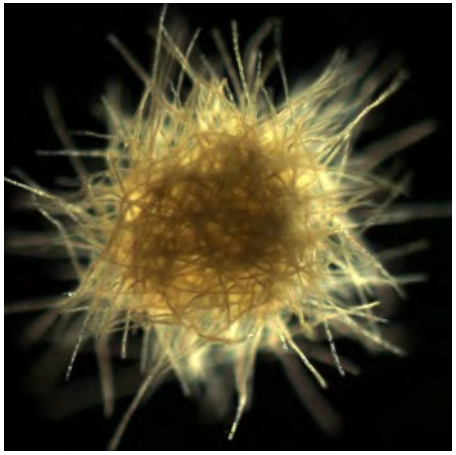
Diazotroph's co-exist where non-diazotrophs are nitrogen limited and $\Phi Fe{:}N > 1$

Tilman (1982), Dutkiewicz et al (GBC, 2012, BG, 2014), Ward et al (L+O, 2013)

- What do the traits/trade-offs mean for their biogeography?

Resource Ratio Theory:

Diazotrophs exist where
1) non-diazotrophs are nitrogen limited
2) there is excess supply of P and Fe relative to non-diazotrophs needs



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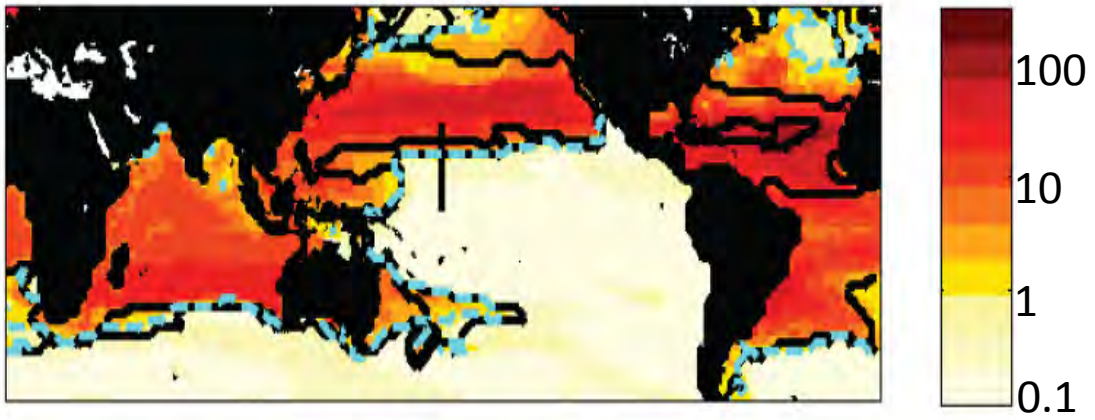
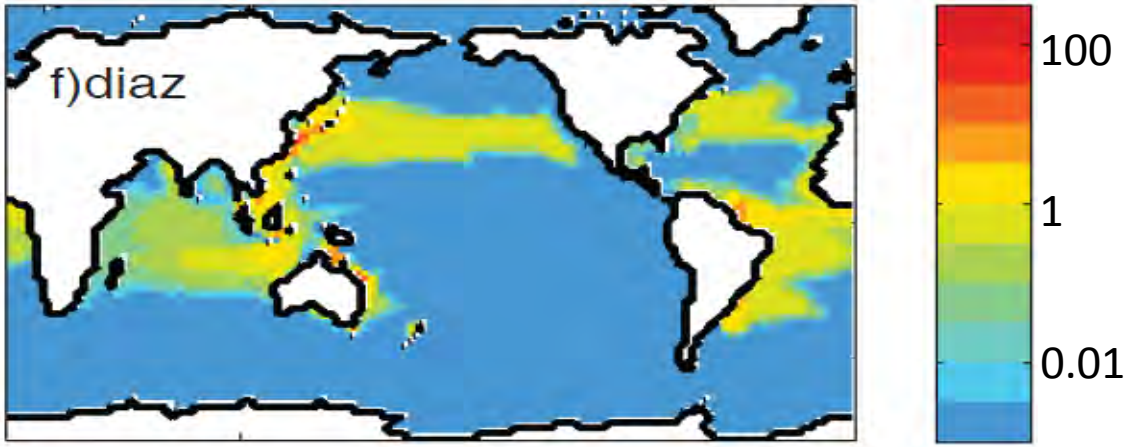


$$\phi_{\mathrm{FeN}} = \frac{I^*_{\mathrm{Fe}}}{R_{\mathrm{NFe_B}} I^*_{\mathrm{N}}}$$

excess supply of Fe



diazotroph biomass (mgC/ m³)

Dutkiewicz et al (BG, 2014)

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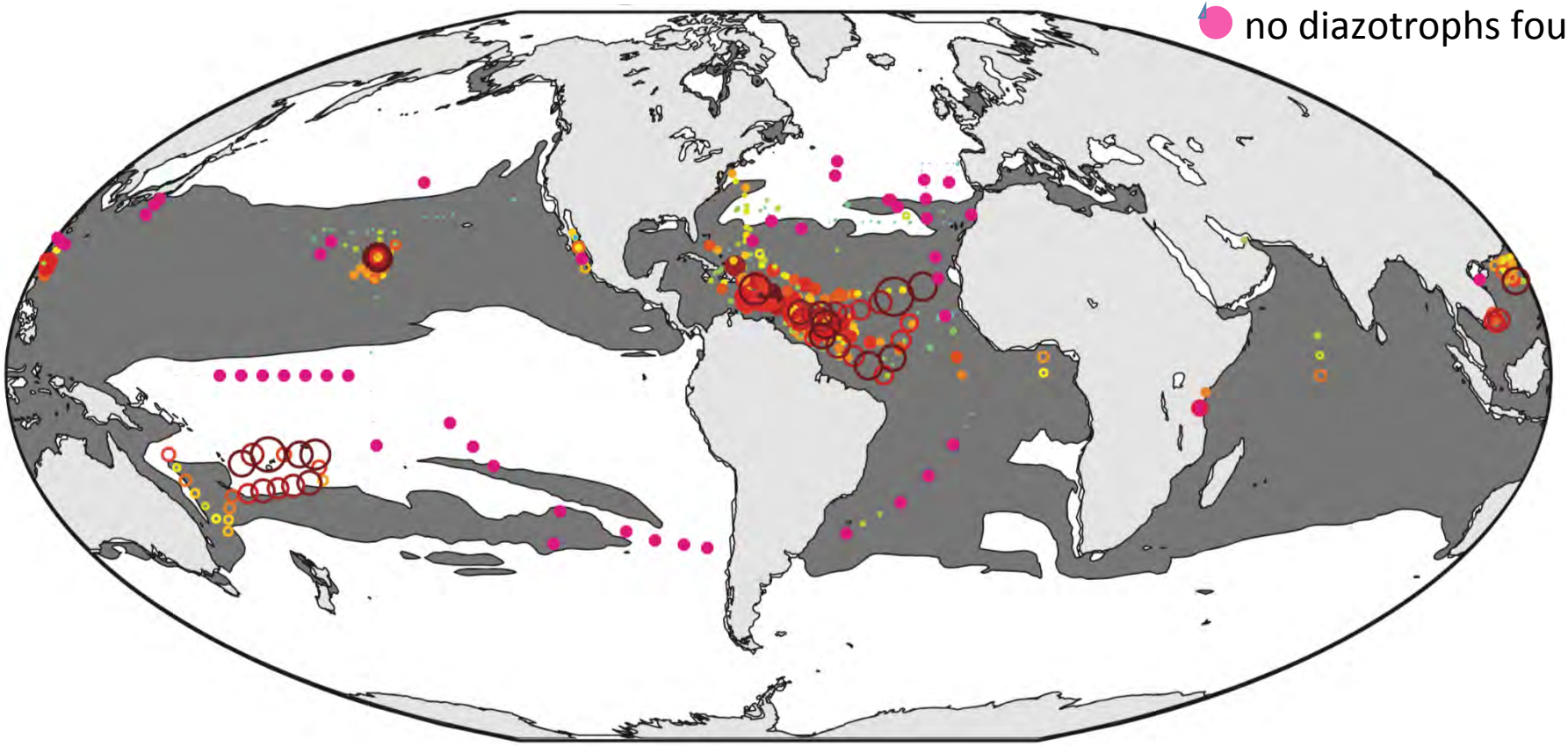

Grey: Model prediction of where there is excess iron sufficient to support diazotrophs

Symbols are from MAREDAT (Luo et al, 2012) compilation of diazotroph occurrence

Ward et al (LO, 2013)

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Datasets are sparse;

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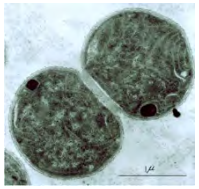
Datasets are sparse

And diazotrophs include a wide variety of types of plankton

- What are the traits/trade-offs of *Trichodesmium*?

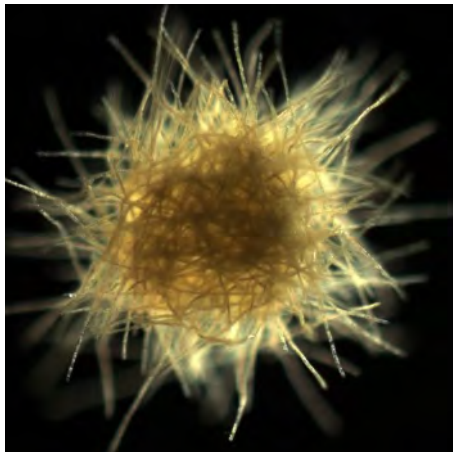
Crocosphaera

3-6um diameter, single cell



Trichodesmium

10um diameter, lives in filaments and colonies



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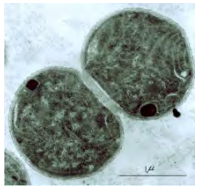

- grows faster
- small, so better at acquiring nutrients

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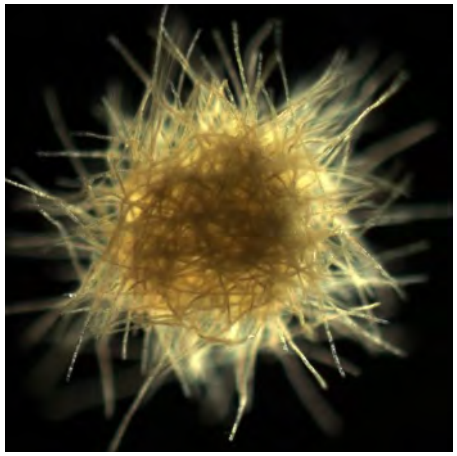

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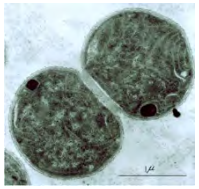

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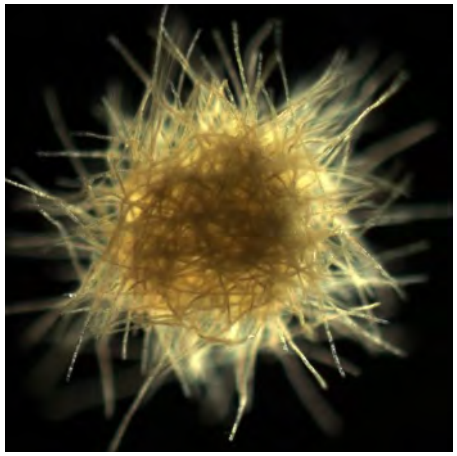

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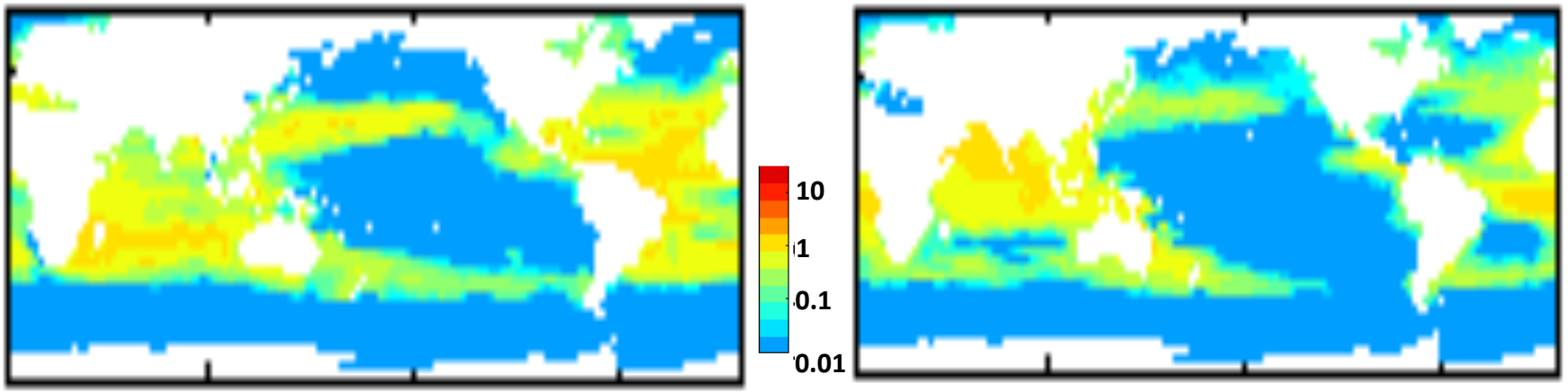

biomass mean over
0-50m (mgC/m^3)

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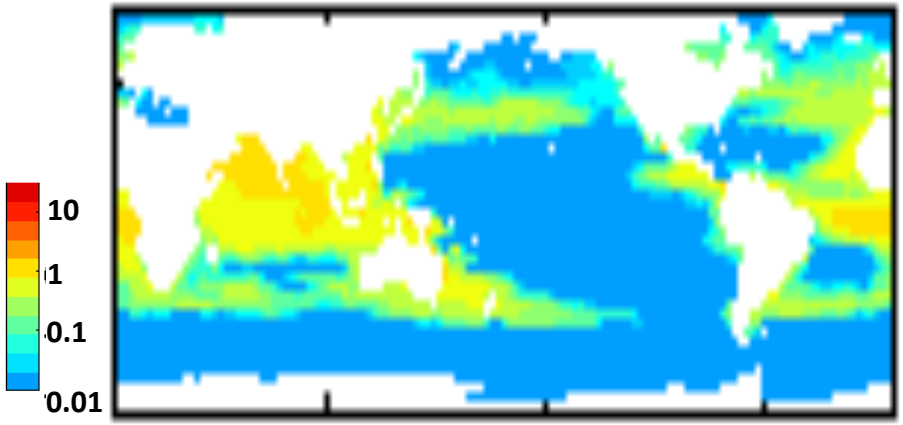
Trichodesmium



biomass mean over 0-50m (mgC/m^3)

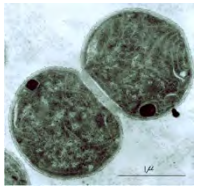
IS THIS DISTRIBUTION CREDIBLE?

- grows slower
- larger, so worse at acquiring nutrients
- **resistance to grazers**

- What are the traits/trade-offs of other diazotroph types?

Crocosphaera

3-6um diameter, single cell



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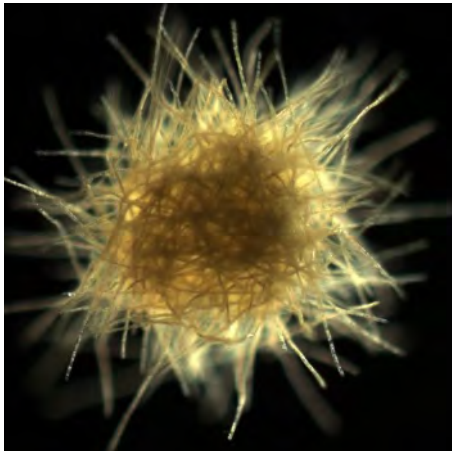
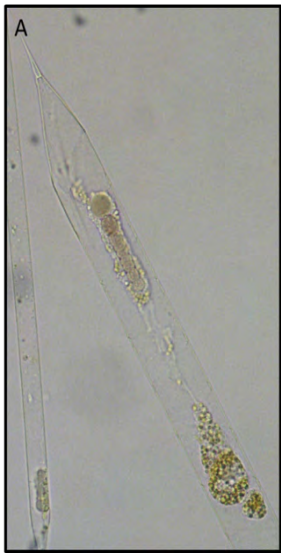
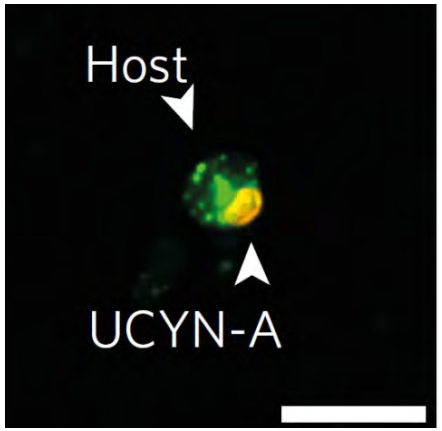




Diatom-Diazotroph Assemblages (DDA)

(Follett et al, ISME, in revision)

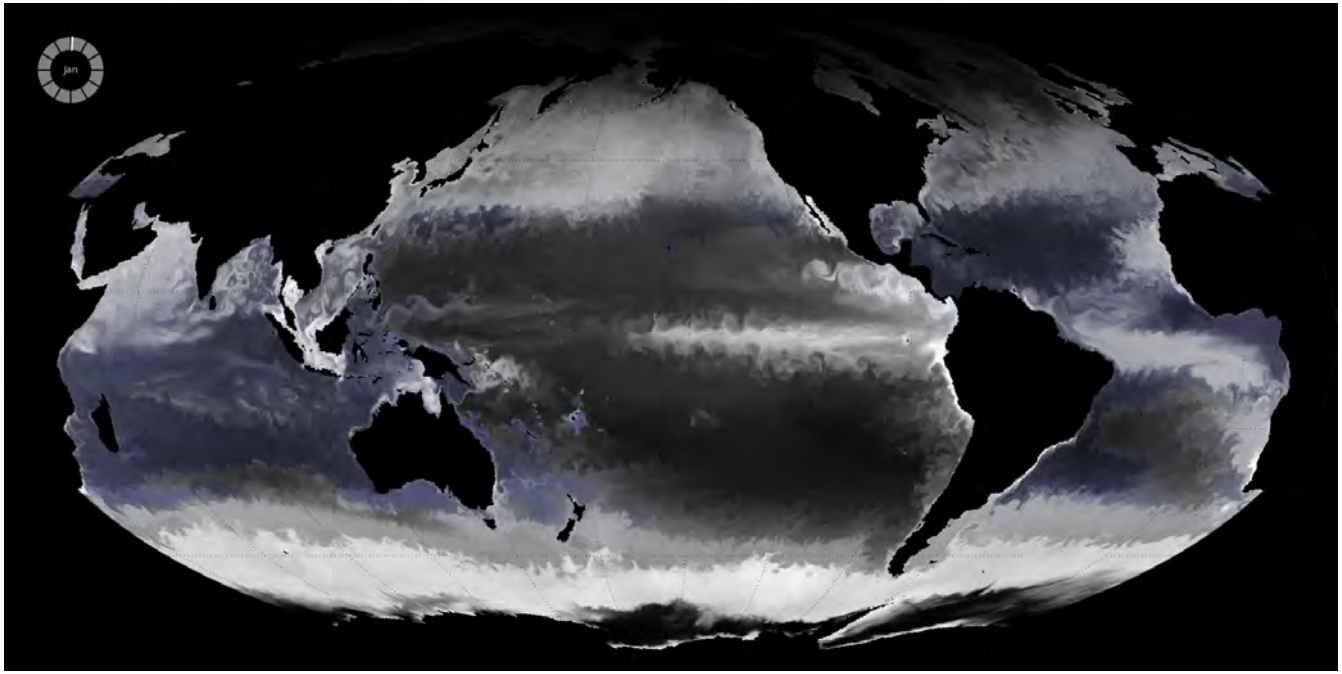


UCYN-A

SUMMARY:

- Theory predicts diazotrophs biogeography controlled by excess supply of P, Fe relative to non-diazotroph needs.
- But data is yet too sparse to make definitive tests.
- Remotely sensed estimates of *Trichodesmium* will go long way to helping define biogeography.

white: model Chl-a



purple: model diazotroph Chl-a