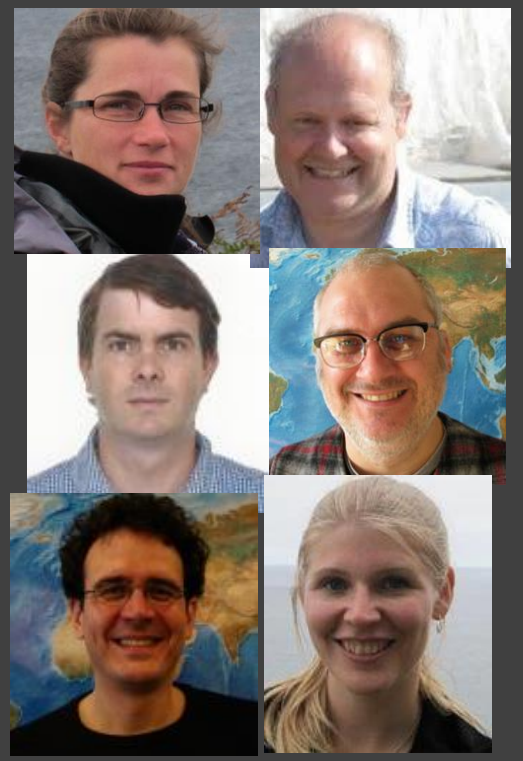
Signatures of the multiple scales of motion in shaping marine phytoplankton biogeography

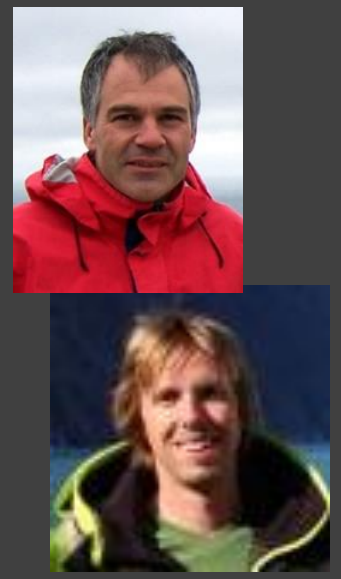
Stephanie Dutkiewicz
Massachusetts Institute of Technology

FTLE from AVISO flow fields
Credit: Mohammad Ashkesari



Massachusetts Institute of Technology:

Stephanie Dutkiewicz
Chris Hill
Gael Forget
Mick Follows
Oliver Jahn
Maike Sonnewald

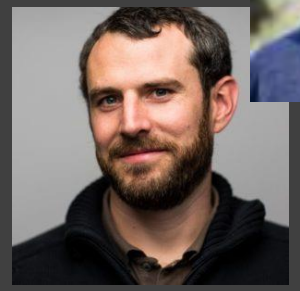


NASA Jet Propulsion Lab:

Dimitris Menemenlis
Dustin Carroll

University of Washington:

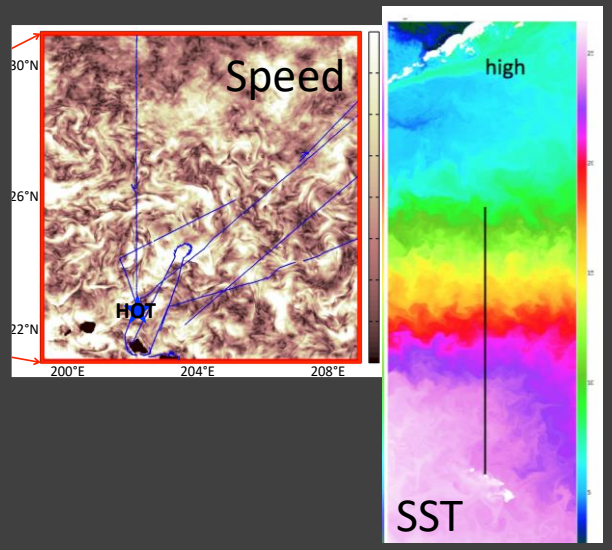
Ginger Armbrust
Francois Ribalet



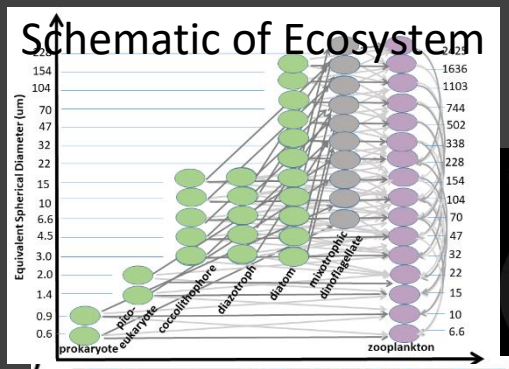
PROJECT GOALS

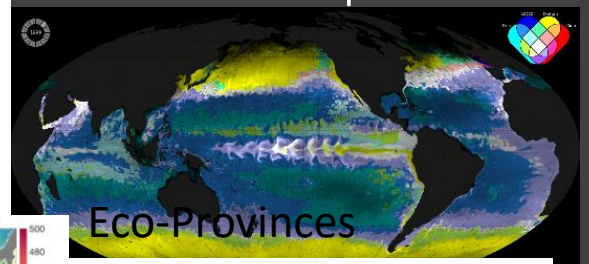
- Describing and understanding dynamic phytoplankton community biogeography from few kms to basin scales
- The observable signatures of these multiscale biogeographical patterns in satellite and in-situ data: how to monitor now and in future
- What is missed when the various scales are not resolved in observations and models

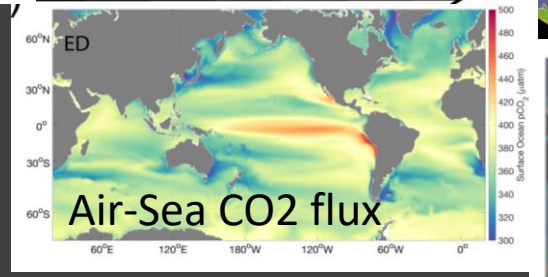
- Data constrained ocean circulation models

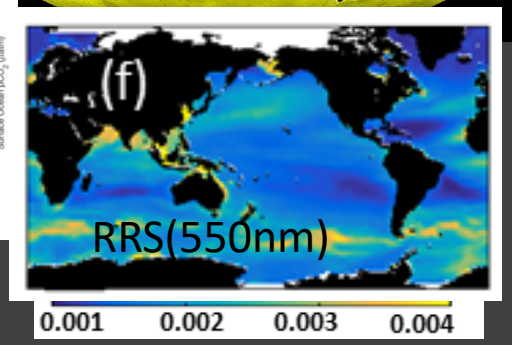


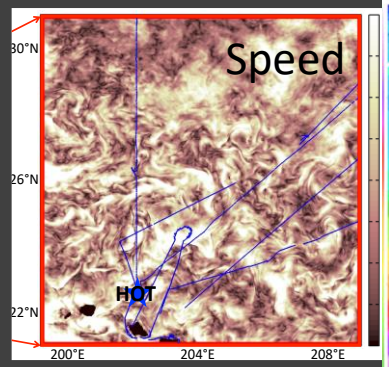
- Data constrained ocean circulation models
- Complex marine ecosystem model

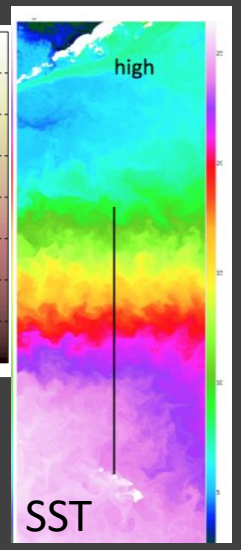












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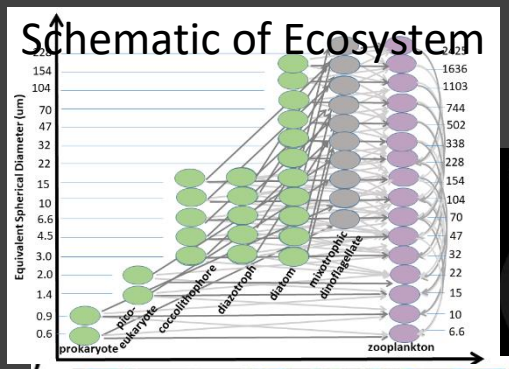
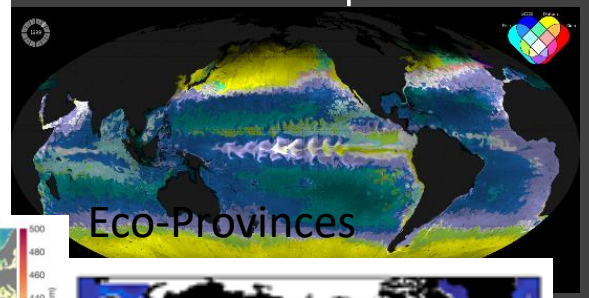
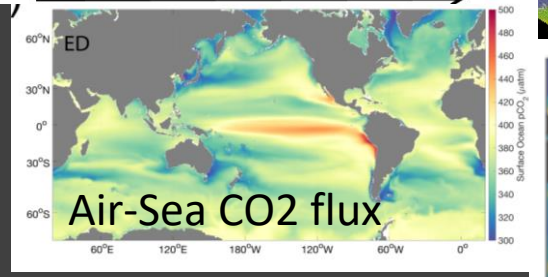
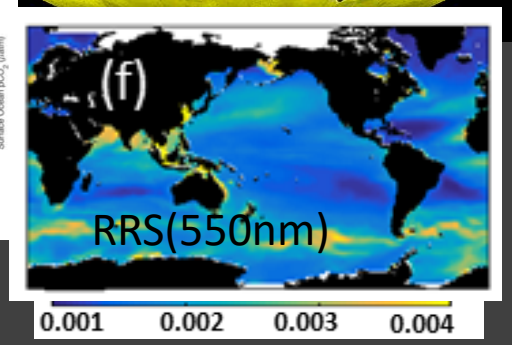
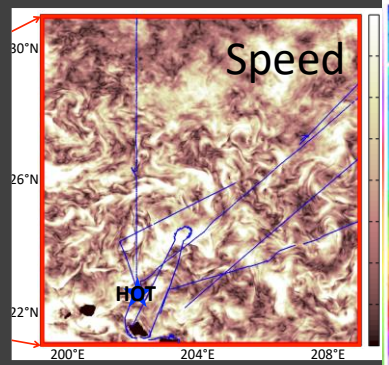


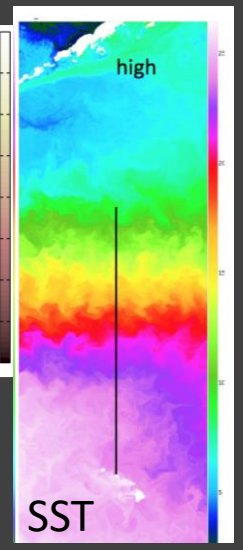


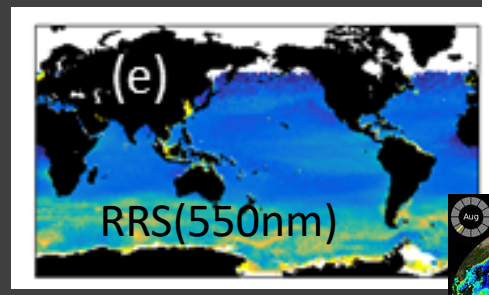


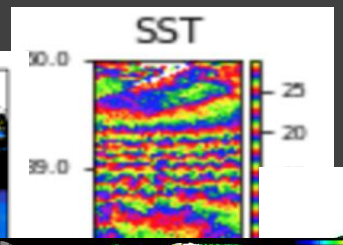


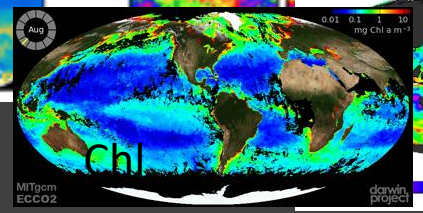
- Satellite data

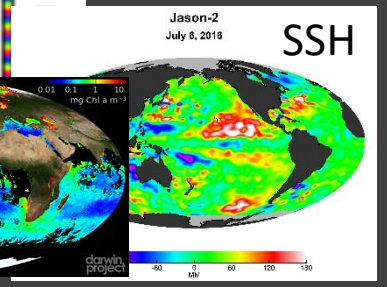












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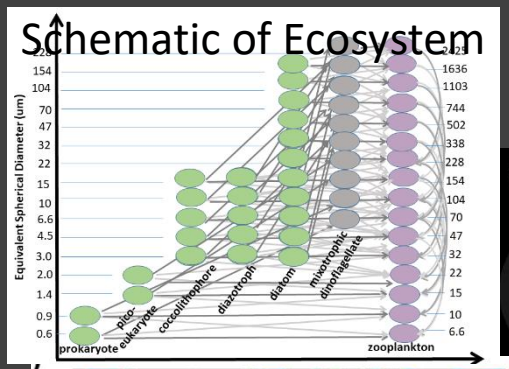
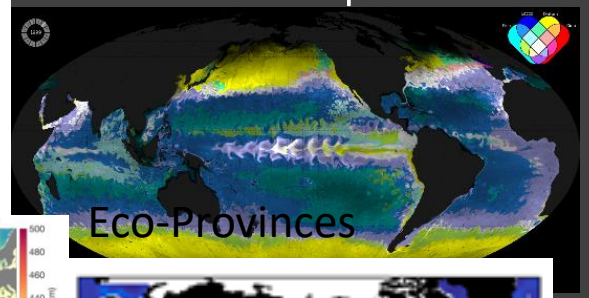
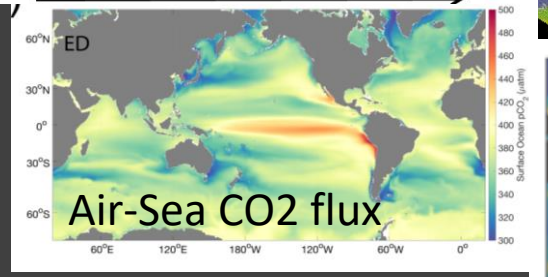
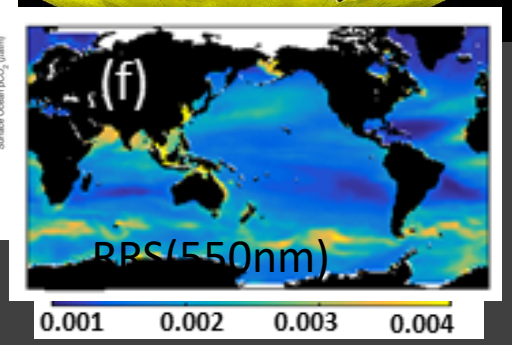
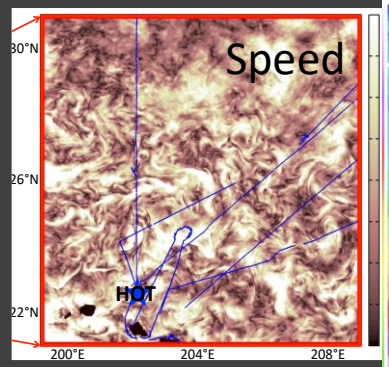


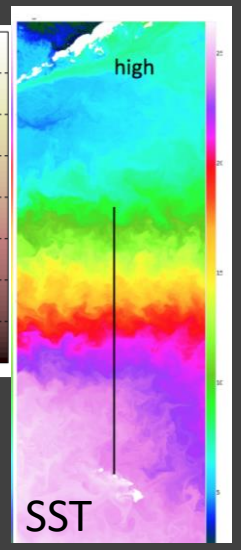


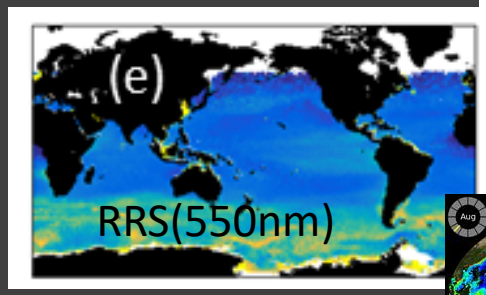


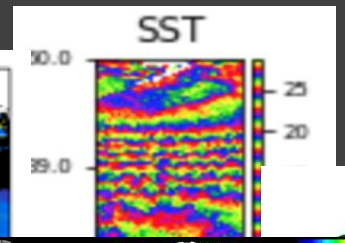


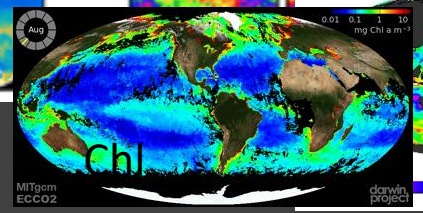
- Satellite data
- High resolution in situ data

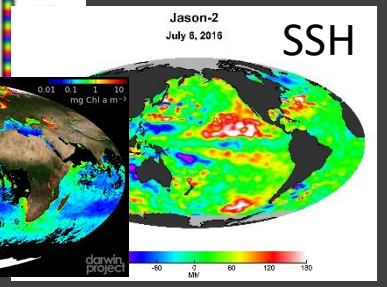


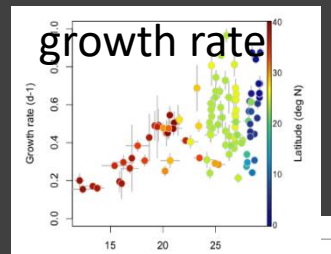


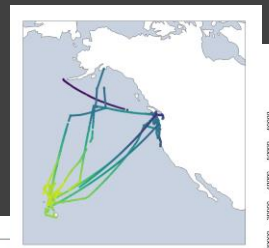


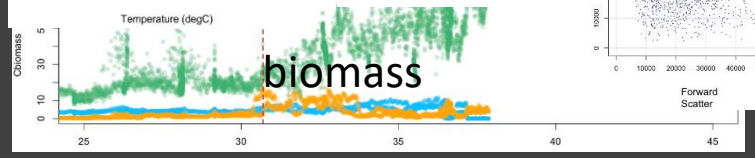


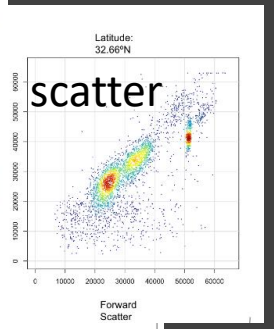


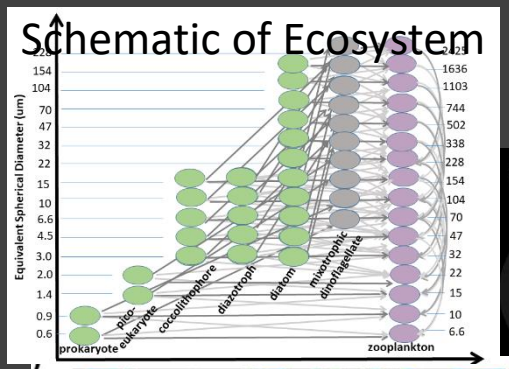












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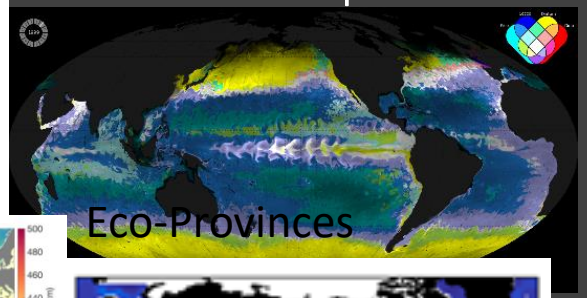

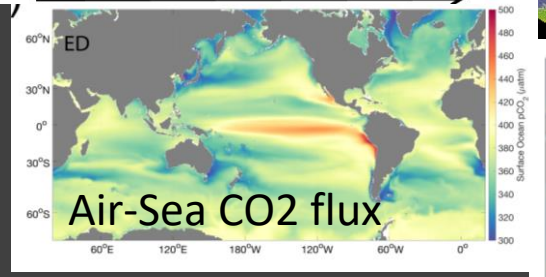

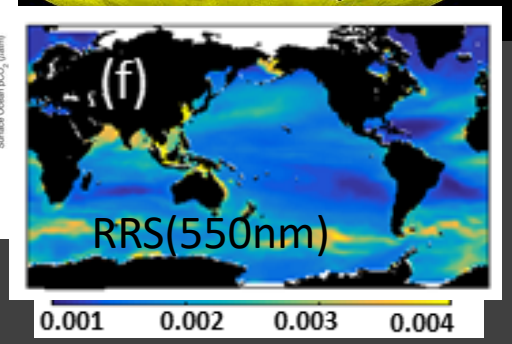

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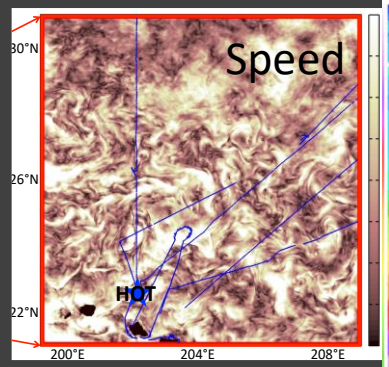
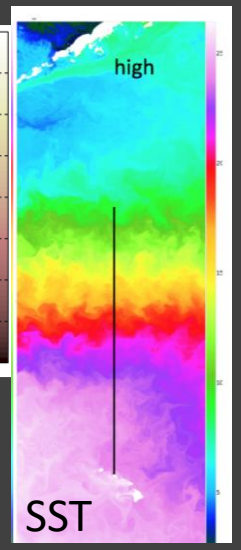
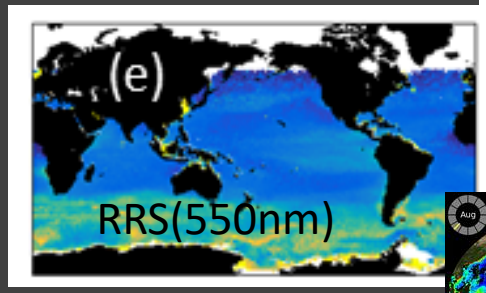
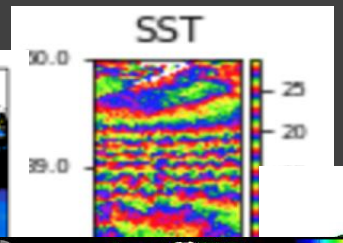
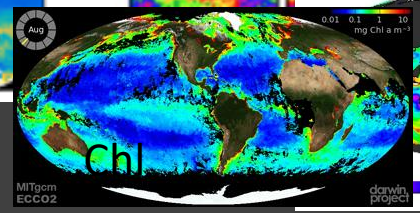
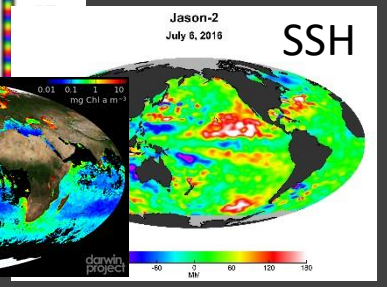


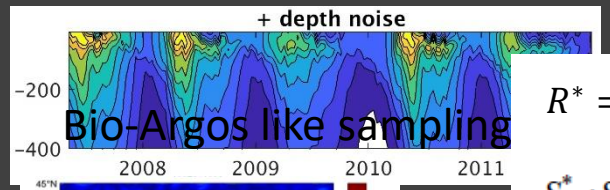






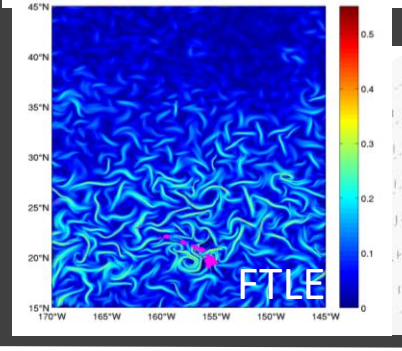


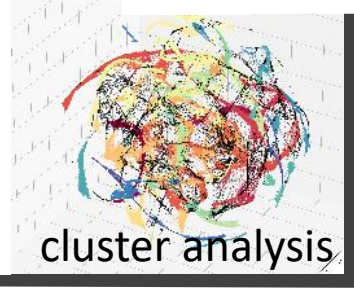




$$R^* = \frac{K_R}{\frac{\mu_m}{M} - 1}$$

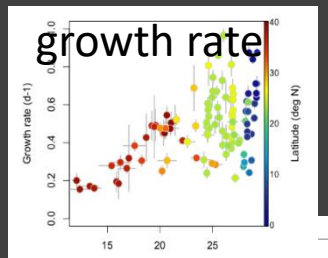
$$S^*_{Fe} : S^*_N \geq R_P$$

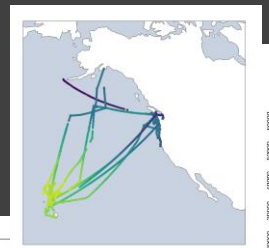


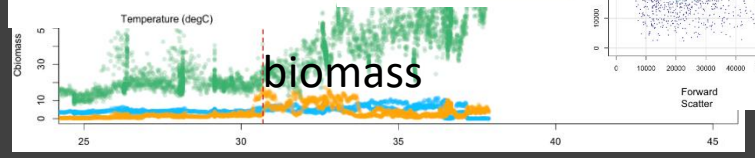


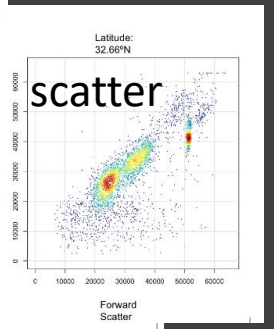
Tools to explore these:

- Machine learning
- Lagrangian tracking
- Subsampling techniques
- Ecological Theory





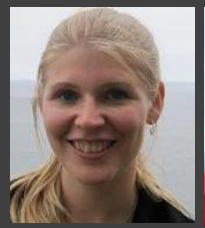


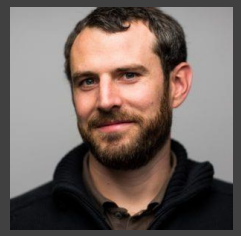


ONGOING PROJECTS

Model Simulations:

- LLC90 (ECCO-v4) 20 year (1 degree)
  – **Forget**
- CS510 (ECCO2) 20 year (18km)
  –**Jahn**
- LLC4320 14 month (2km)
  –**Jahn**, **Hill**

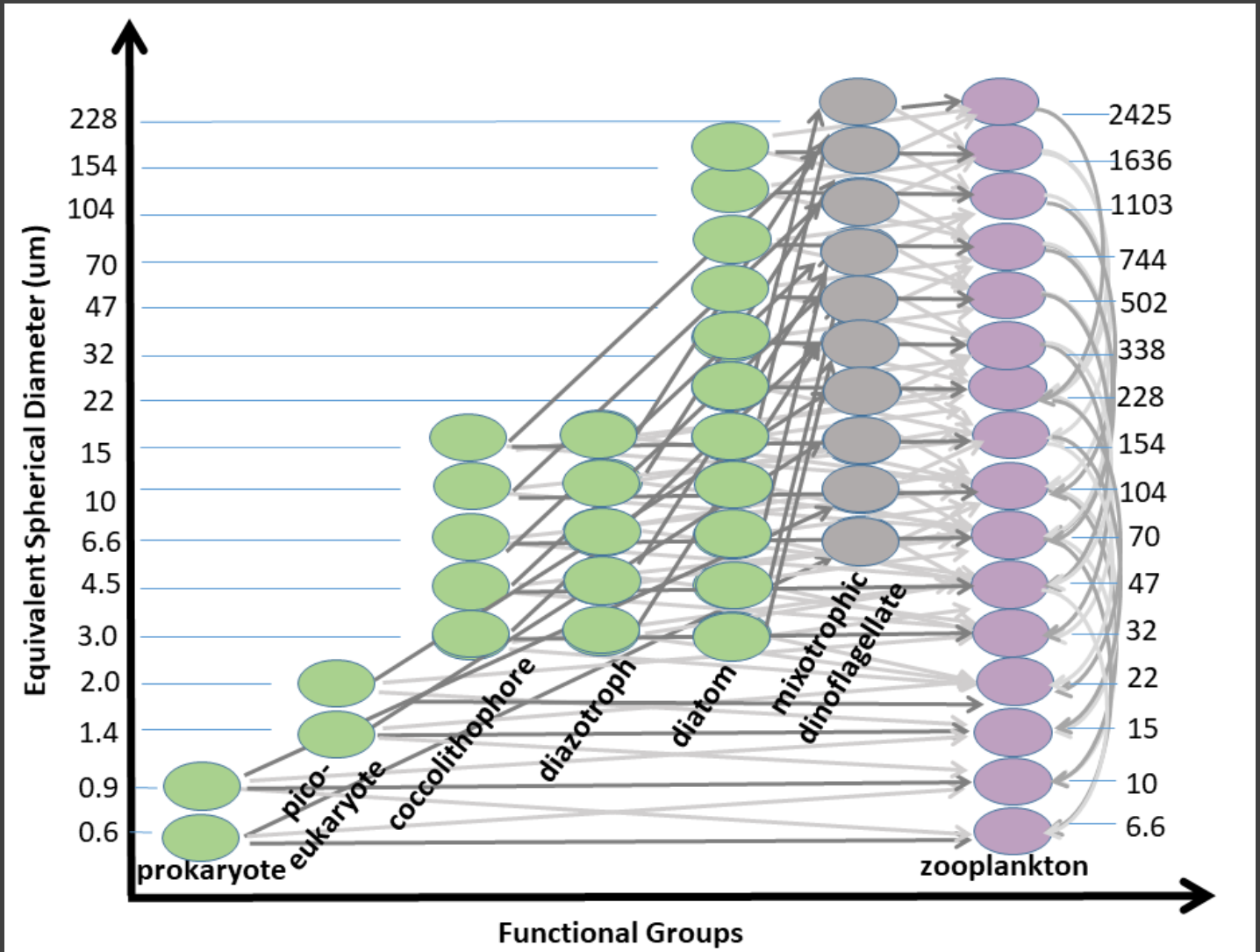






Projects:

- Model study of role of sub- and mesoscale affecting communities (Magnolte, Levy, **Dutkiewicz, Jahn**, Clayton)
- Co-location SeaFlow and satellite to explore mesoscale structuring of pico-phytoplankton (Cape, **Ribalet, Armbrust,** Hynes, Ashakezari)
- Model Study of phytoplankton decorrelations scales (Kuhn, **Dutkiewicz, Jahn,** Clayton, Rynearson, Barton)
- Nutrient and temperature controls on *Prochlorrococcus* growth rates (**Ribalet, Dutkiewicz, Armbrust**, Casey)
- Defining eco-provinces with unsupervised machine learning **(Sonnewald, Dutkiewicz, Hill, Forget)**
- Modelling the response of marine ecosystems to lava fertilization (**Jahn, Dutkiewicz, Hill**, Wilson, Hawco, Karl et al)
- Constraining air-sea carbon fluxes in a model (**Carroll, Menemenlis, Dutkiewicz,** et al)
- Modelling BioArgos floats for determining optimal monitoring of marine biogeochemistry and ecology (**Forget**)
- Determining carbon biomass of pico-phytoplankton assemblages from SeaFlow cell Counts (**Ribalet**, **Armbrust,** Cape, Hynes, Ashakezari et al)
- Scales of plankton competition versus Lagrangian dispersal (Rahmandan, Britten, **Follows, Hill**)

ECOSYSTEM MODEL



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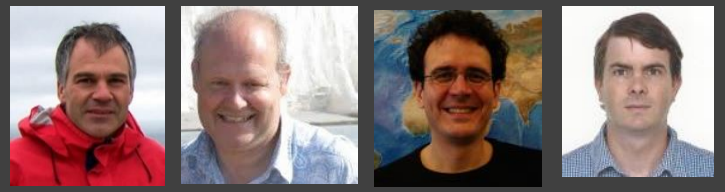
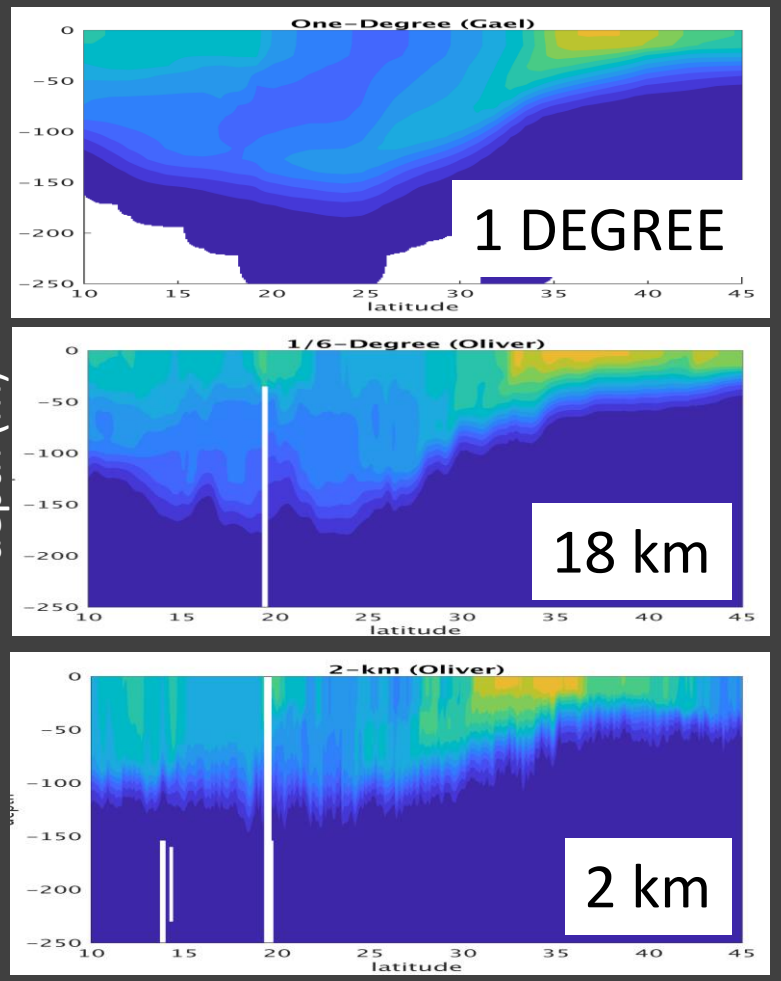
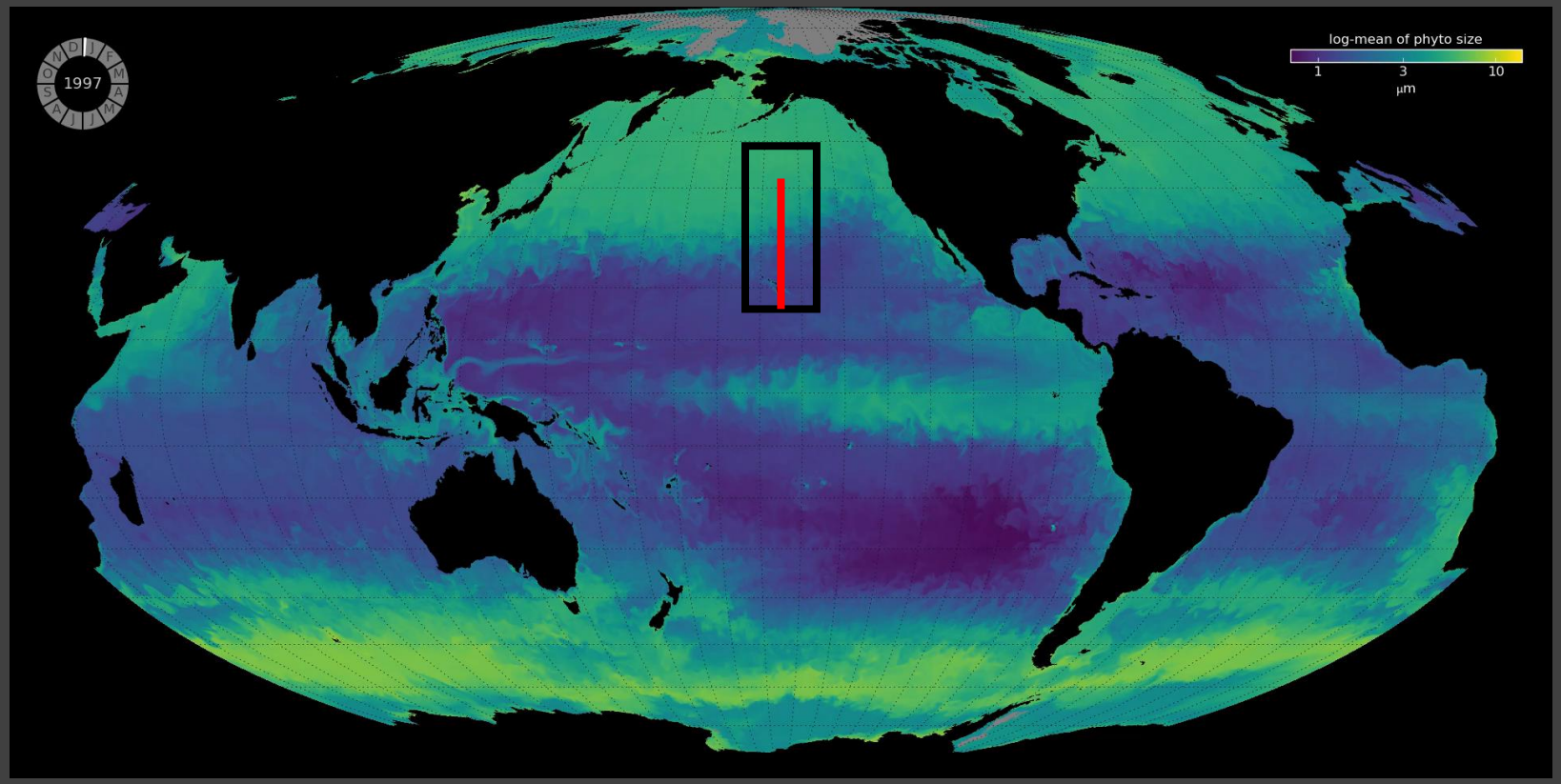


Dimiris Menemenlis *Chris Hill* *Oliver Jahn* *Gael Forget*

Biomass of Smallest Phytoplankton (mmol C/m^3)



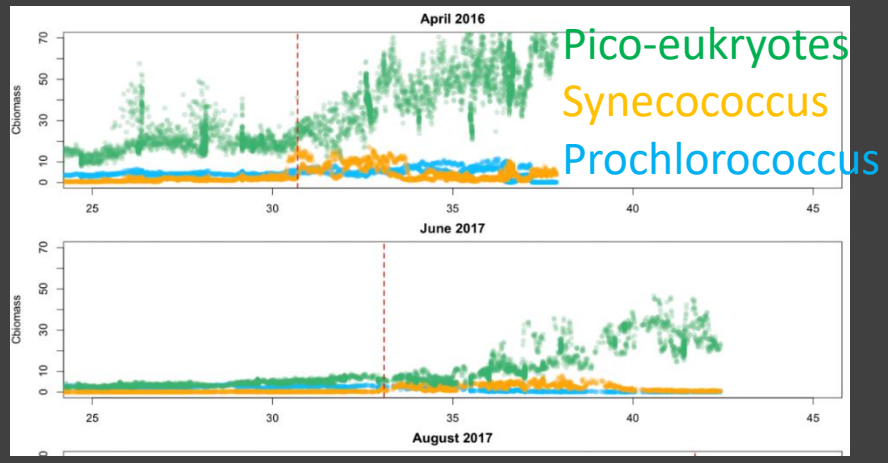
log-mean of phytoplankton size (ESD)



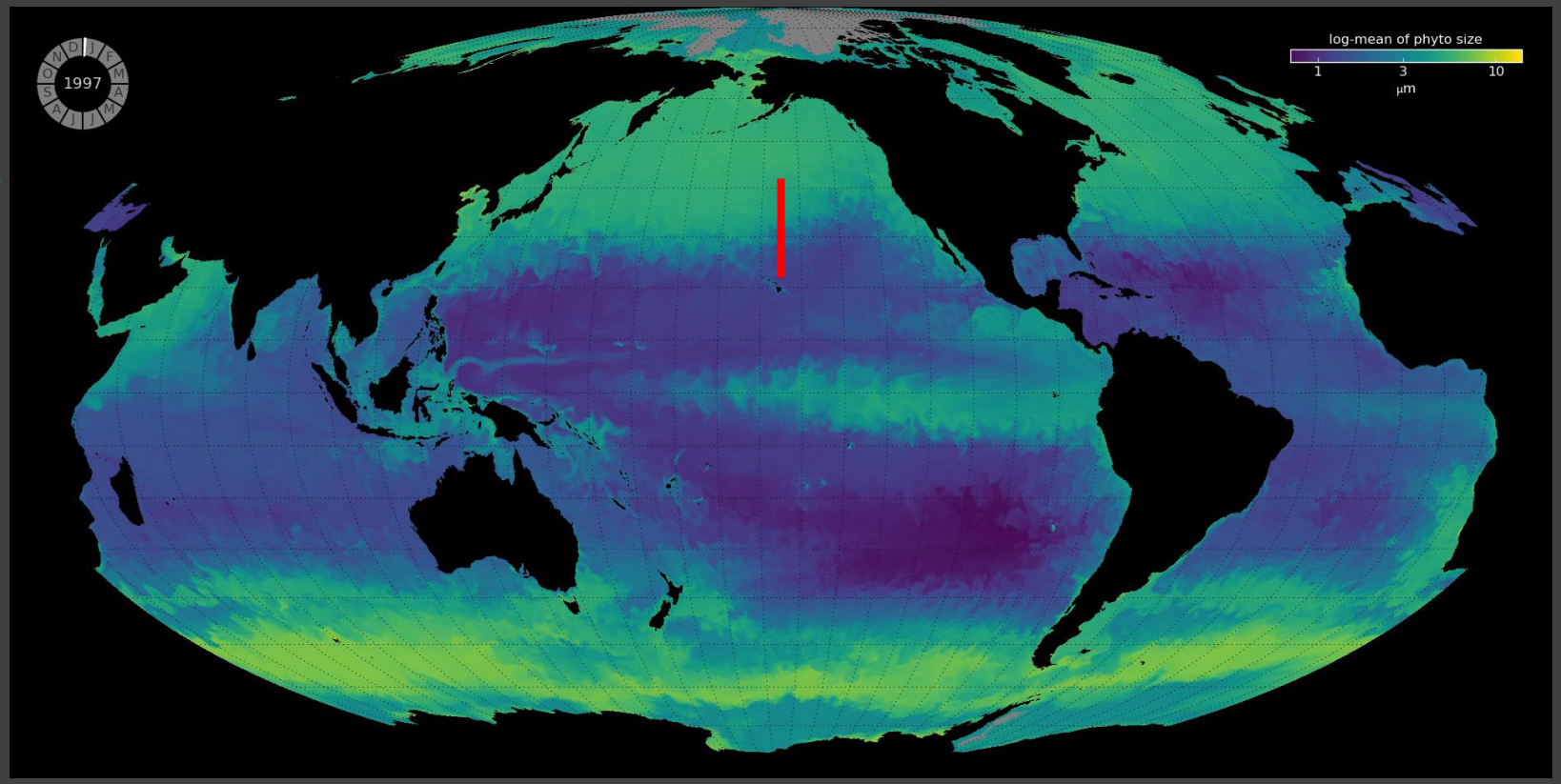
ECOSYSTEM MODEL

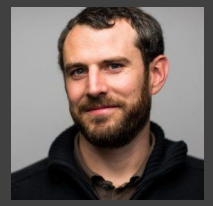
Oliver Jahn

Biomass from Continuous Flow Cytometer



log-mean of phytoplankton size (ESD)

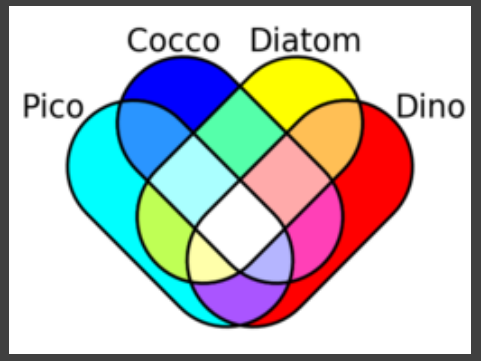




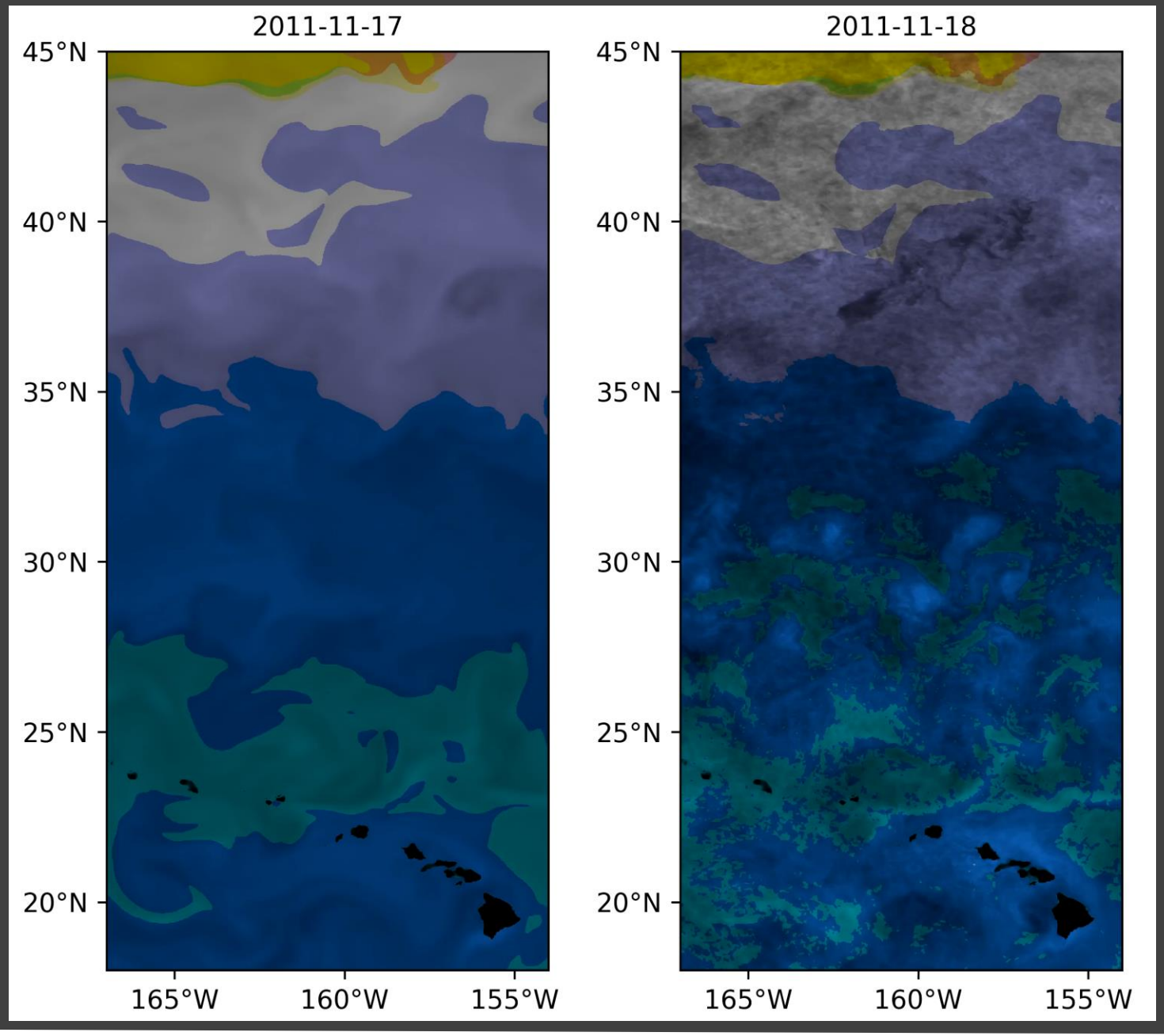
Francois Ribalet

Ginger Armbrust

Phytoplankton communities



18 km resolution



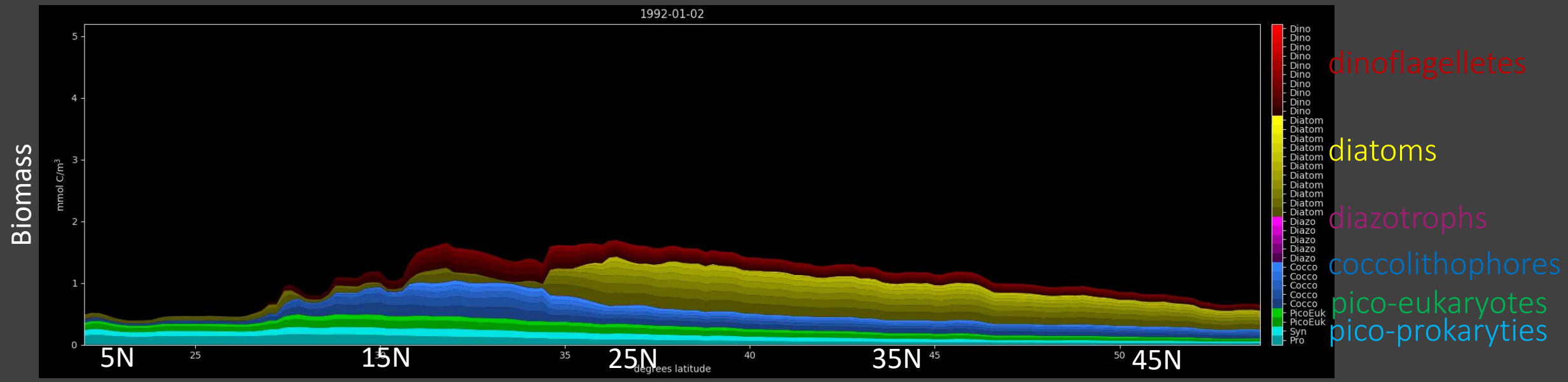
Oliver Jahn

Chris Hill

2 km resolution

Phytoplankton communities

Oliver Jahn



Transect in N Pacific

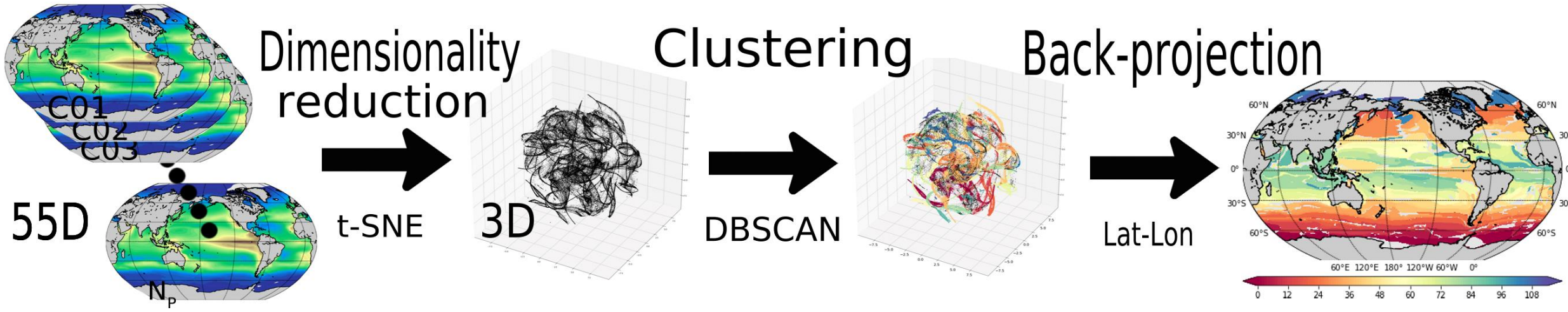
18 km resolution

DEFINING ECO-PROVINCES

see poster

Maike Sonnewald

Machine learning tools to cluster similar grid cells into provinces

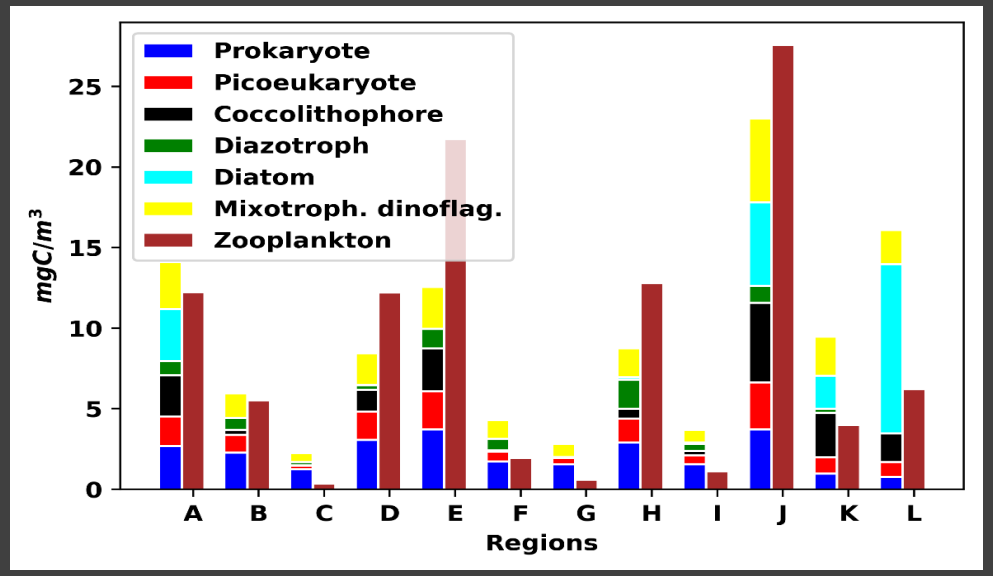


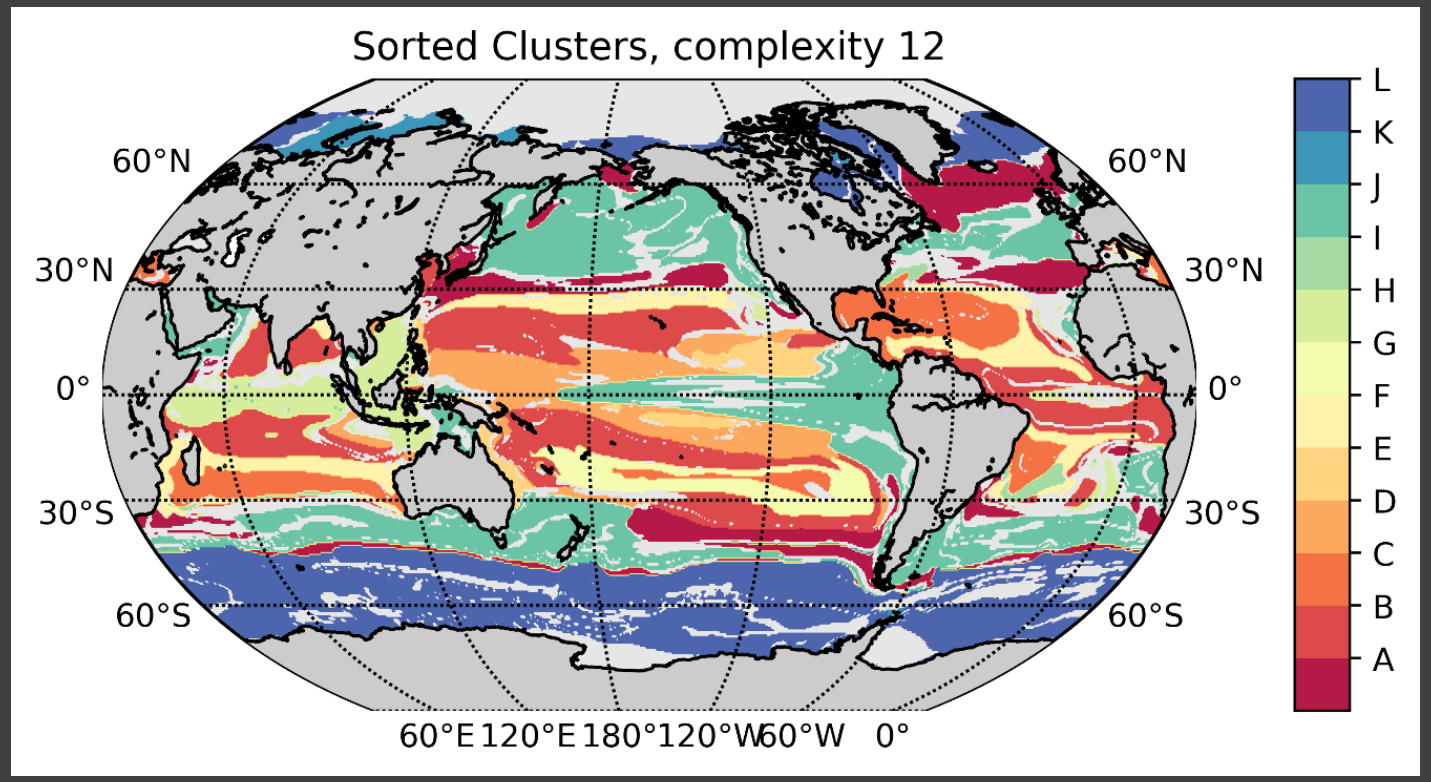
using 1 degree resolution model

DEFINING ECO-PROVINCES

see poster

Maike Sonnewald





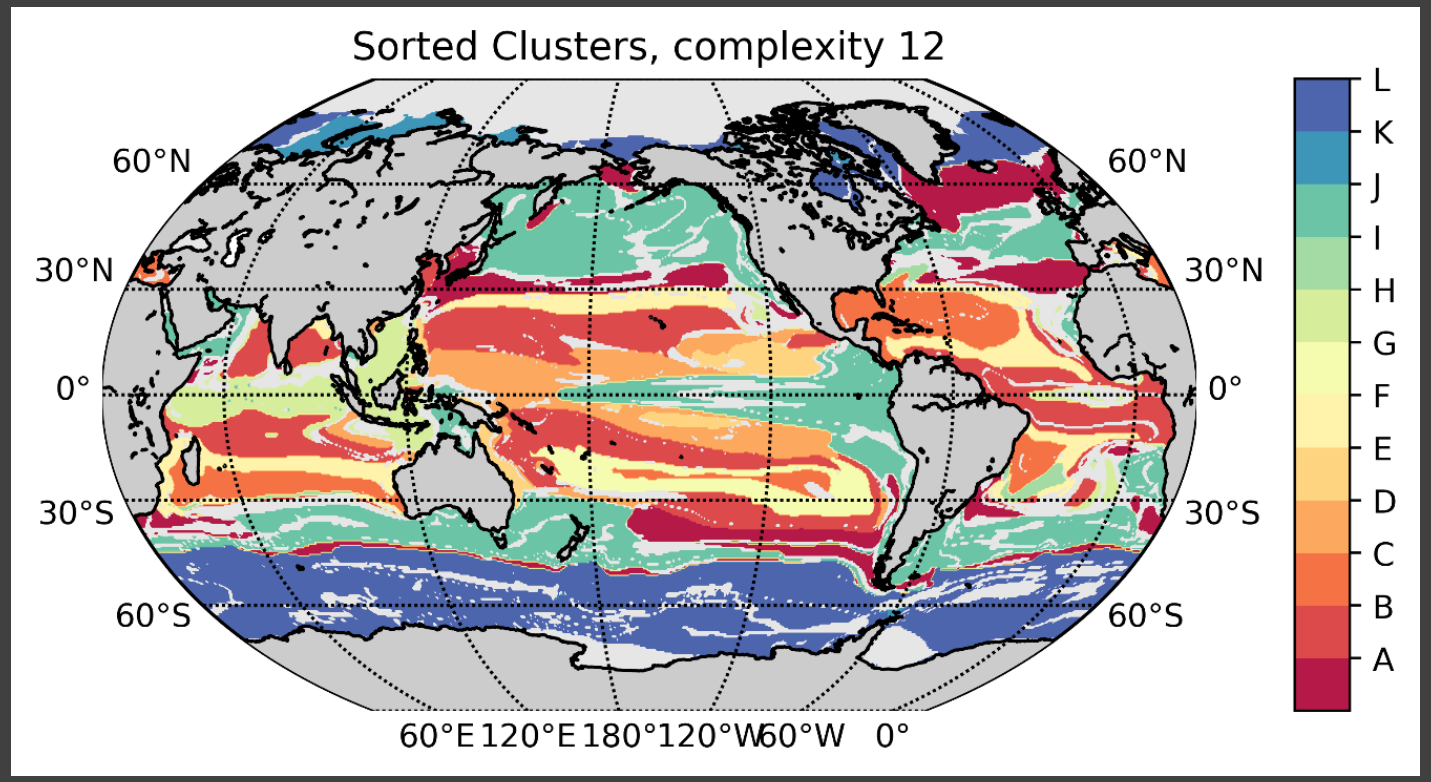
DETECTING ECO-PROVINCES

see poster

Maike Sonnewald

Future work:

- Dynamic regions
- How much of these eco-provinces can we detect from space: use model R_{RS}, SST, SSH, Chl, MLD, PAR
- Scale to finer resolution models



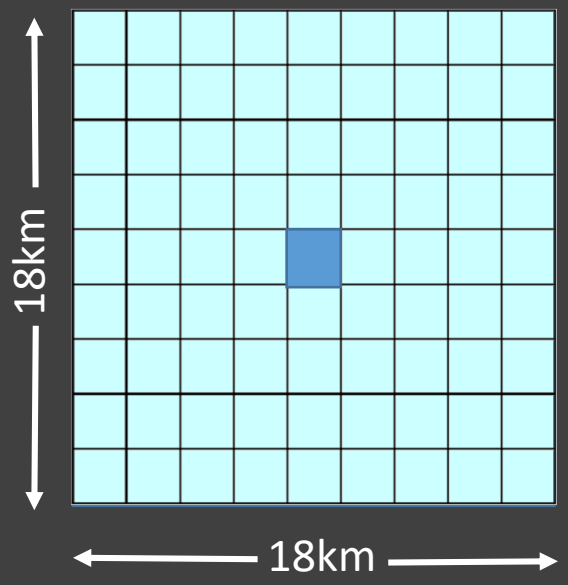
using 1 degree resolution model

SCALES OF COMMUNITY STRUCTURE

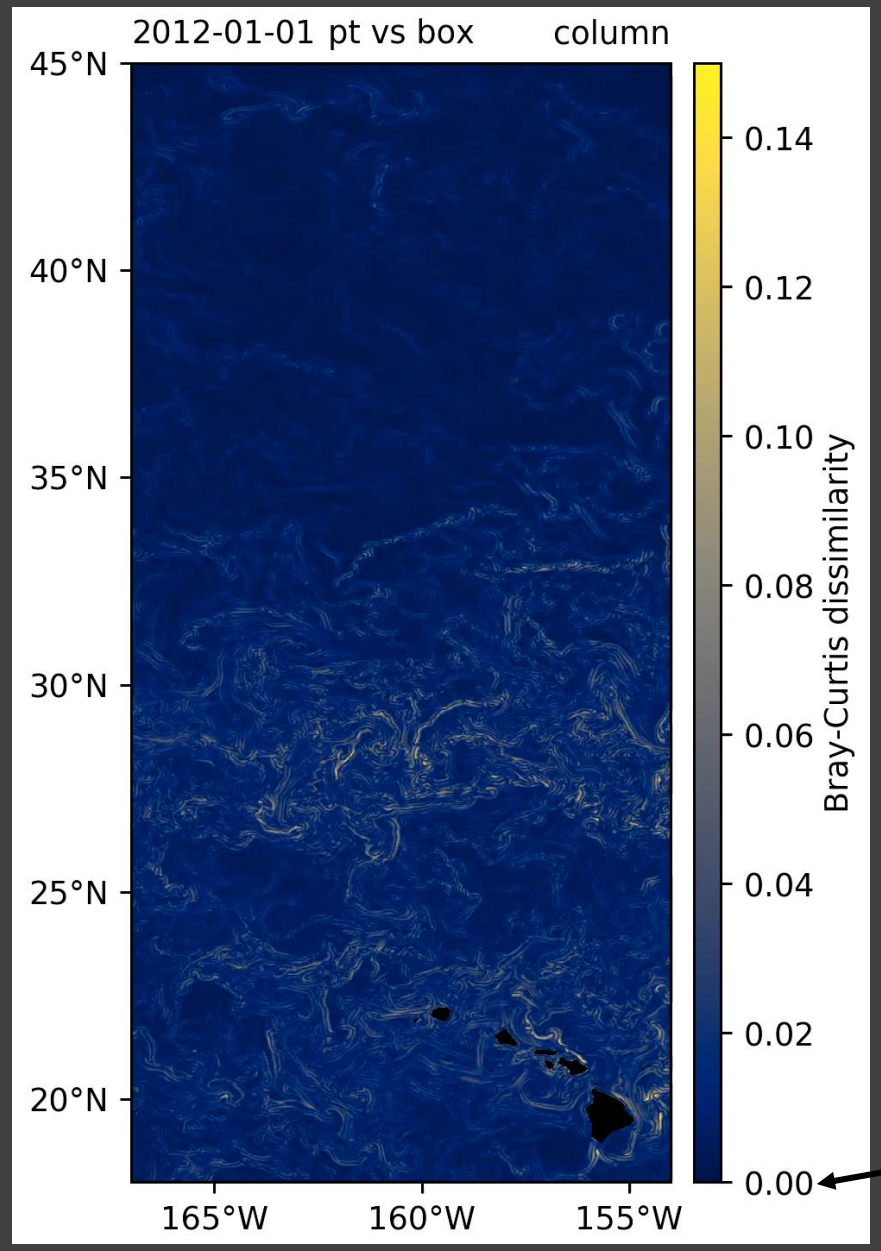
Brey-Curtis dissimilarity:

$$C_{g_i \widehat{g_{i+}}} = 1 - \frac{2\sum_{j=1}^{j=n} \min(B_{jg_i}, B_{j\widehat{g_{i+}}})}{\sum_{j=1}^{j=n} B_{jg_i} + \sum_{j=1}^{j=n} B_{j\widehat{g_{i+}}}}$$

B_j biomass of each of 35 phytoplankton



mean of 9x9 grid cells relative to the center grid cell



identical communities

Oliver Jahn

Chris Hill

2 km resolution

SCALES OF COMMUNITY STRUCTURE

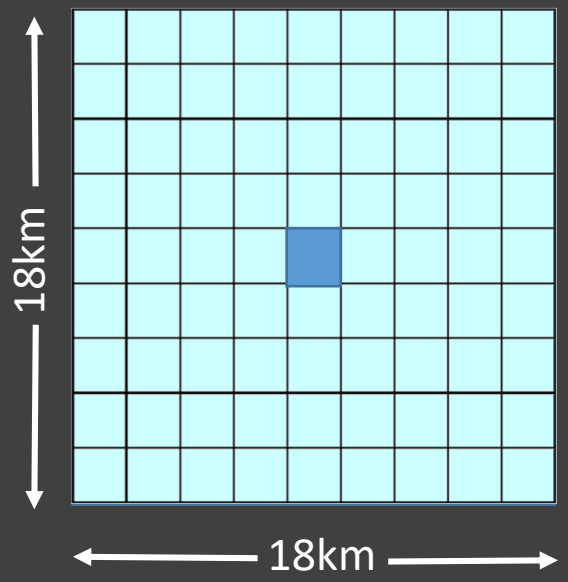
Oliver Jahn

Chris Hill

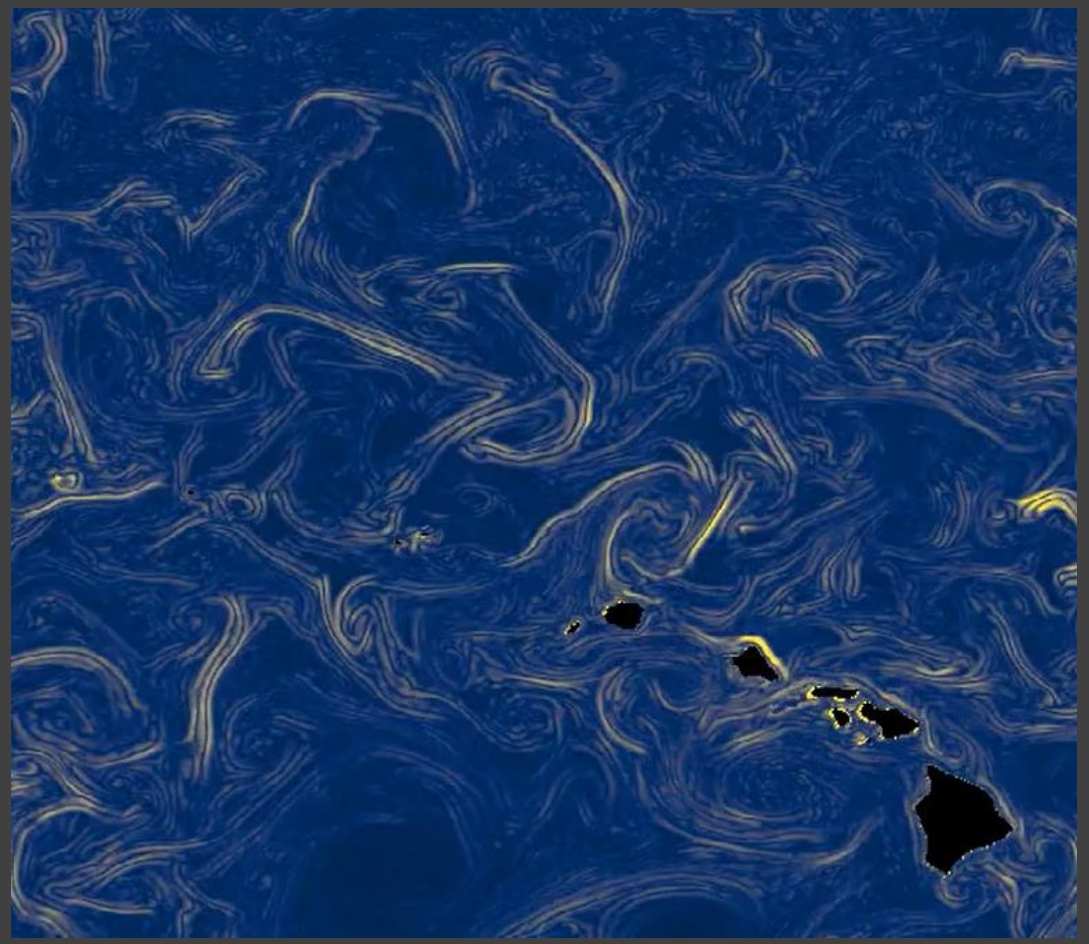
Brey-Curtis dissimilarity:

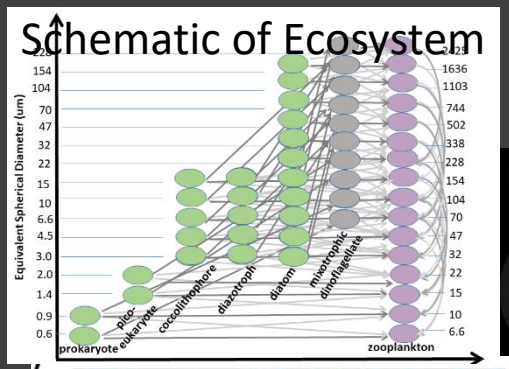
$$C_{g_i\widehat{g_{i+}}} = 1 - \frac{2\sum_{j=1}^{j=n} \min(B_{jg_i}, B_{j\widehat{g_{i+}}})}{\sum_{j=1}^{j=n} B_{jg_i} + \sum_{j=1}^{j=n} B_{j\widehat{g_{i+}}}}$$

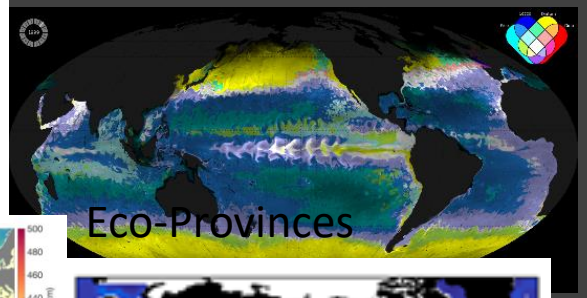
B_j biomass of each of 35 phytoplankton

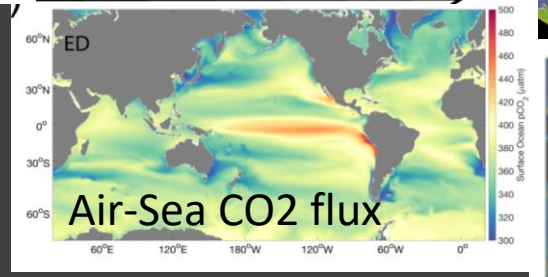


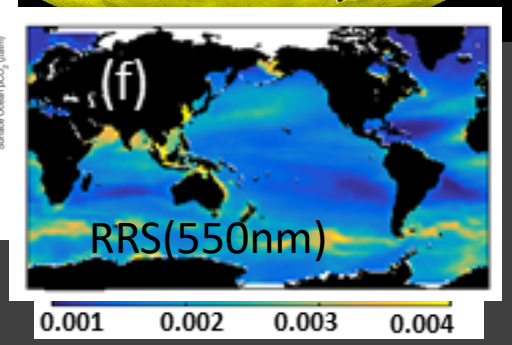
mean of 9x9 grid cells relative to the center grid cell











JPL:

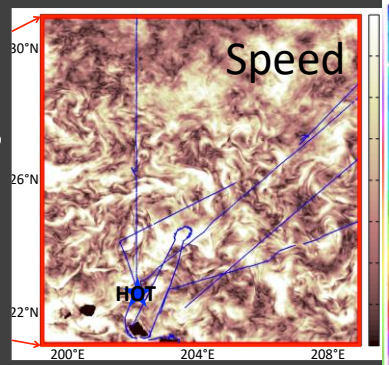
Dimitris Menemenlis

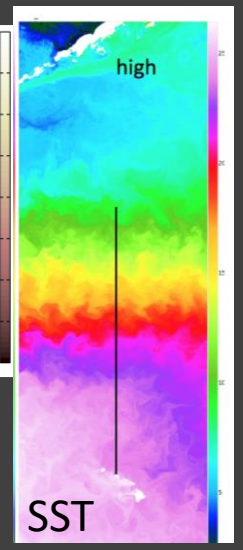
Dustin Carroll

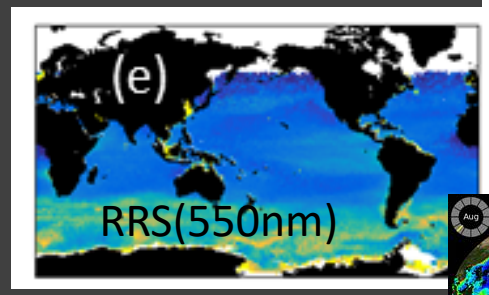
UW:

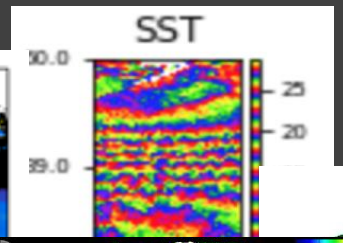
Ginger Armbrust

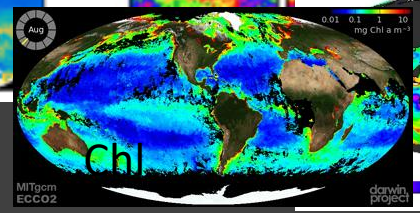
Francois Ribalet

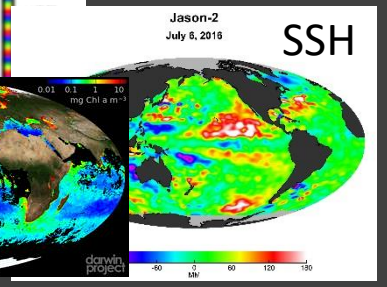


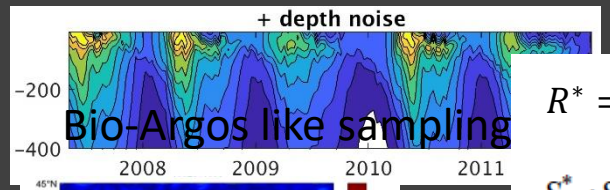






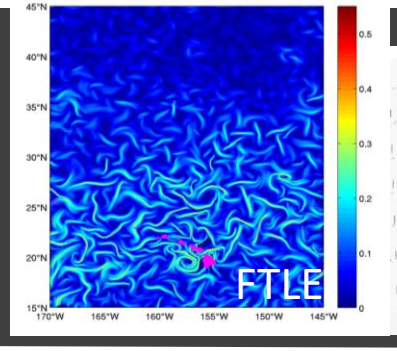


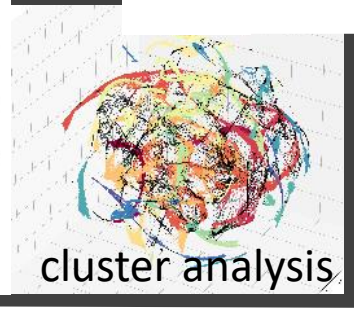




$$R^* = \frac{K_R}{\frac{\mu_m}{M} - 1}$$

$$S^*_{Fe} : S^*_N \geq R_P$$





MIT

Stephanie Dutkiewicz

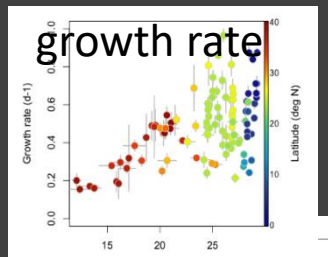
Chris Hill

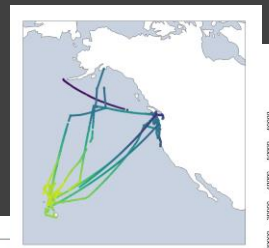
Gael Forget

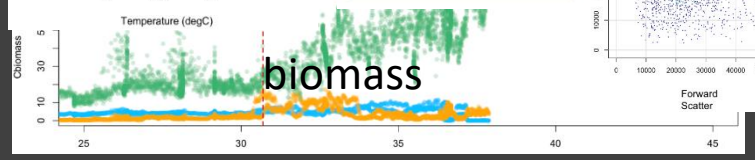
Mick Follows

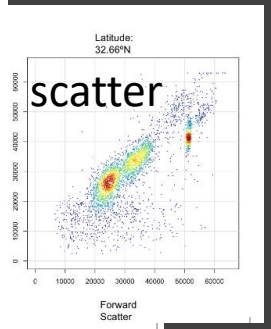
Oliver Jahn

Maike Sonnewald









ONGOING PROJECTS

Model Simulations:

- LLC90 (ECCO-v4) 20 year (1 degree)
  - **Forget**
- CS510 (ECCO2) 20 year (18km)
  - **Jahn**
- LLC4320 14 month (2km)
  - **Jahn**, **Hill**

Projects:

- Model study of role of sub- and mesoscale affecting communities (Magnolte, Levy, **Dutkiewicz, Jahn**, Clayton)
- Co-location SeaFlow and satellite to explore mesoscale structuring of pico-phytoplankton (Cape, **Ribalet, Armbrust,** Hynes, Ashakezari)
- Model Study of phytoplankton decorrelations scales (Kuhn, **Dutkiewicz, Jahn,** Clayton, Rynearson, Barton)
- Nutrient and temperature controls on *Prochlorrococcus* growth rates (**Ribalet, Dutkiewicz, Armbrust**, Casey)
- Defining eco-provinces with unsupervised machine learning **(Sonnewald, Dutkiewicz, Hill, Forget)**
- Modelling the response of marine ecosystems to lava fertilization (**Jahn, Dutkiewicz, Hill**, Wilson, Hawco, Karl et al)
- Constraining air-sea carbon fluxes in a model (**Carroll, Menemenlis, Dutkiewicz,** et al)
- Modelling BioArgos floats for determining optimal monitoring of marine biogeochemistry and ecology (**Forget**)
- Determining carbon biomass of pico-phytoplankton assemblages from SeaFlow cell Counts (**Ribalet**, **Armbrust,** Cape, Hynes, Ashakezari et al)
- Scales of plankton competition versus Lagrangian dispersal (Rahmandan, Britten, **Follows, Hill**)

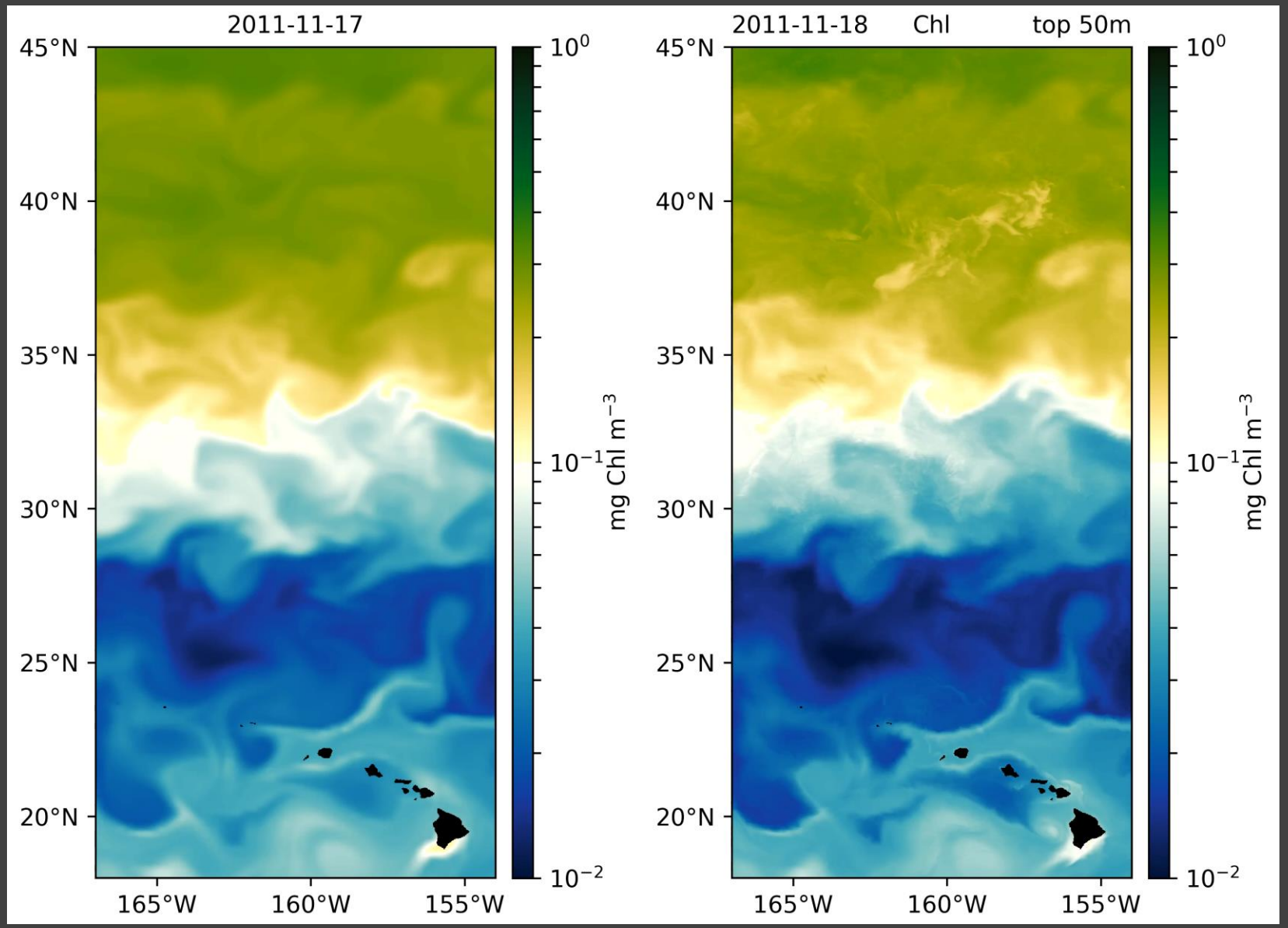
TITLE

MODEL Chl-a

Oliver Jahn

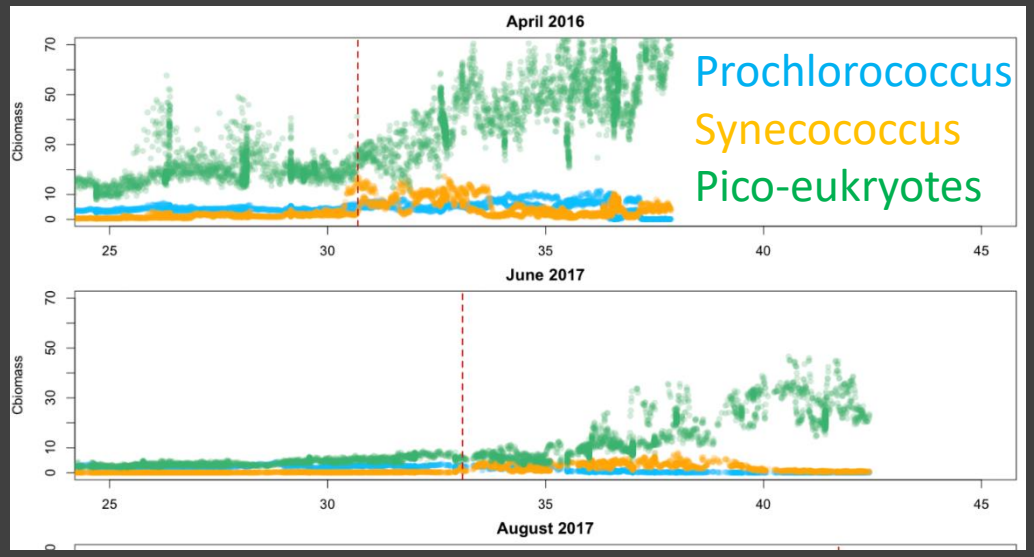
Chris Hill

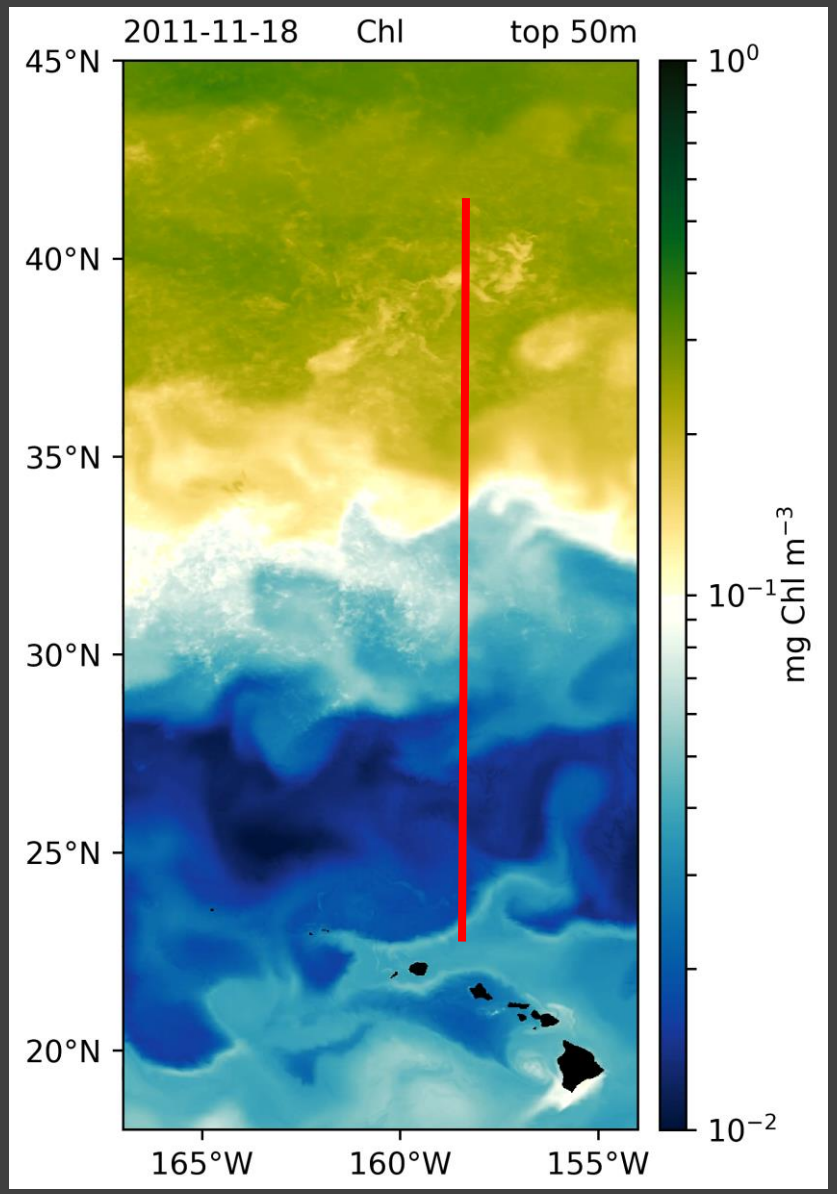
18 km resolution



2 km resolution

LINKS TO IN SITU DATA

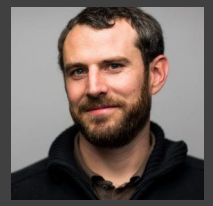




Oliver Jahn

Chris Hill

2 km resolution



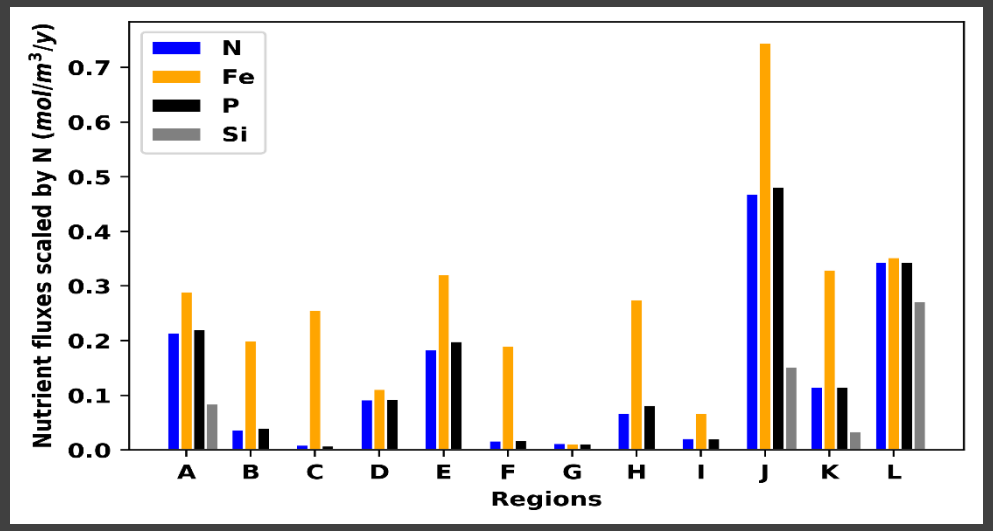
Francois Ribalet

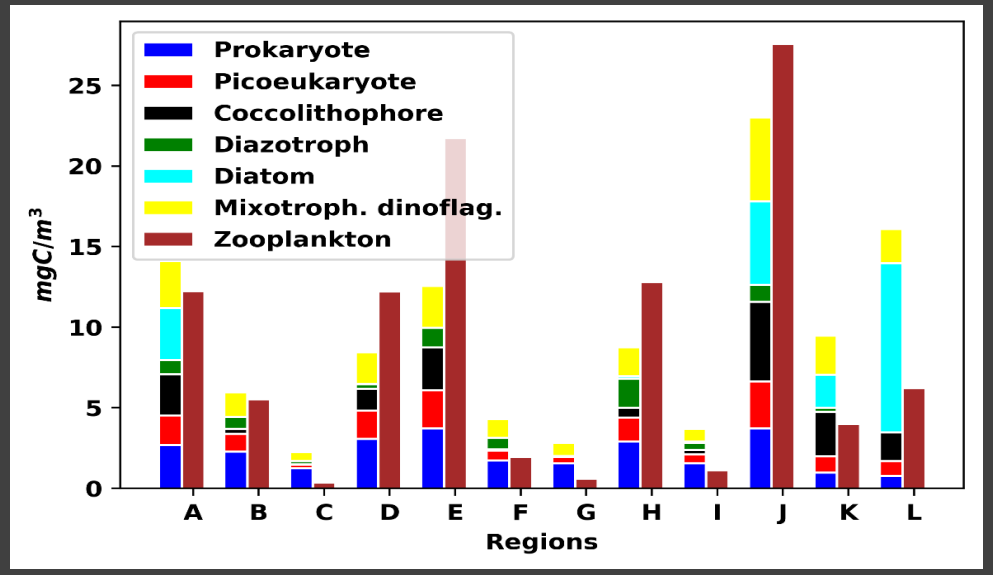
Ginger Armbrust

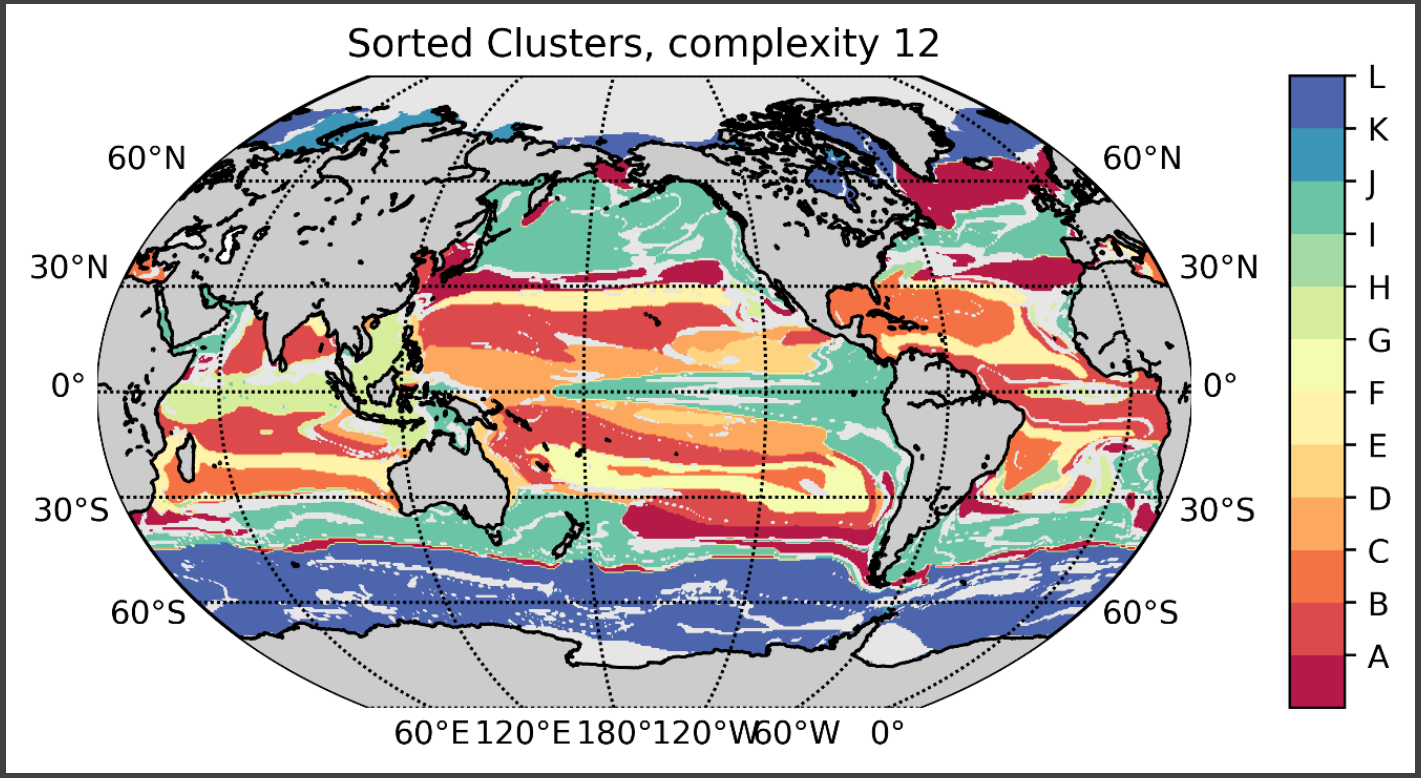
UNDERSTANDING ECO-PROVINCES

see poster

Maike Sonnewald







using 1 degree resolution model

ONGOING PROJECTS

Dutkiewicz: *Signatures of the Multiple Scales of Motion in Shaping Marine Phytoplankton Biogeography*