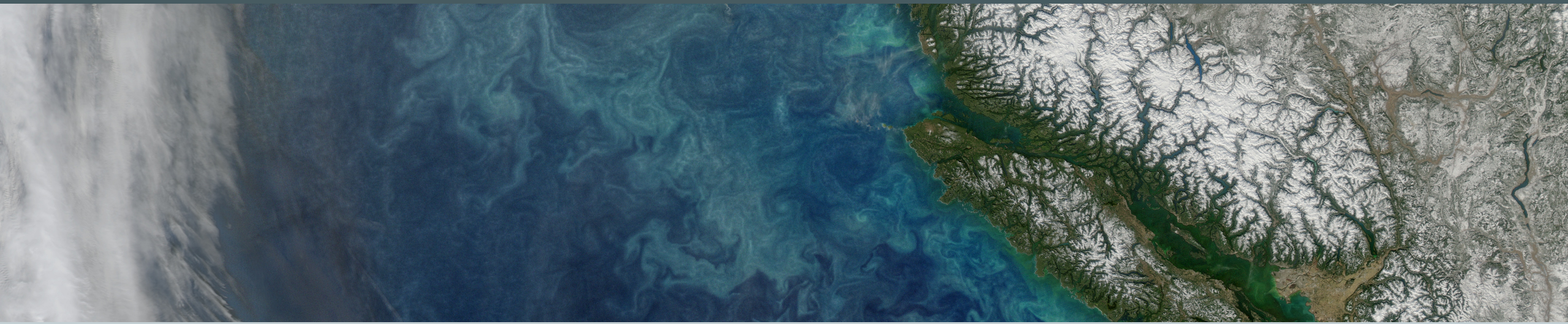
Implementing a satellite emulator in CESM2 to evaluate the impact of clouds on ocean chlorophyll observations

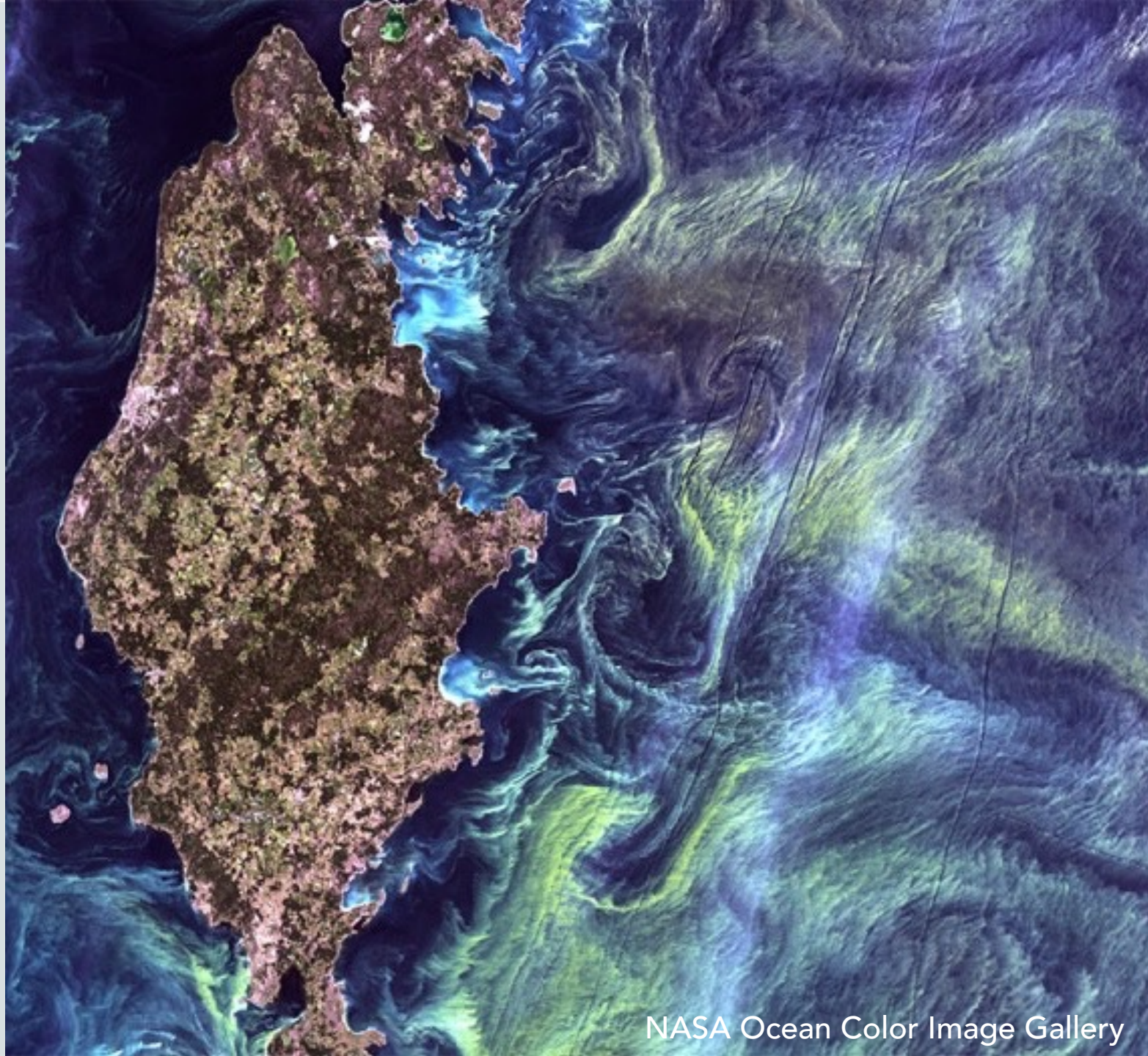
Genevieve Clow, Nikki Lovenduski, Mike Levy, Keith Lindsay & Jen Kay



University of Colorado Boulder

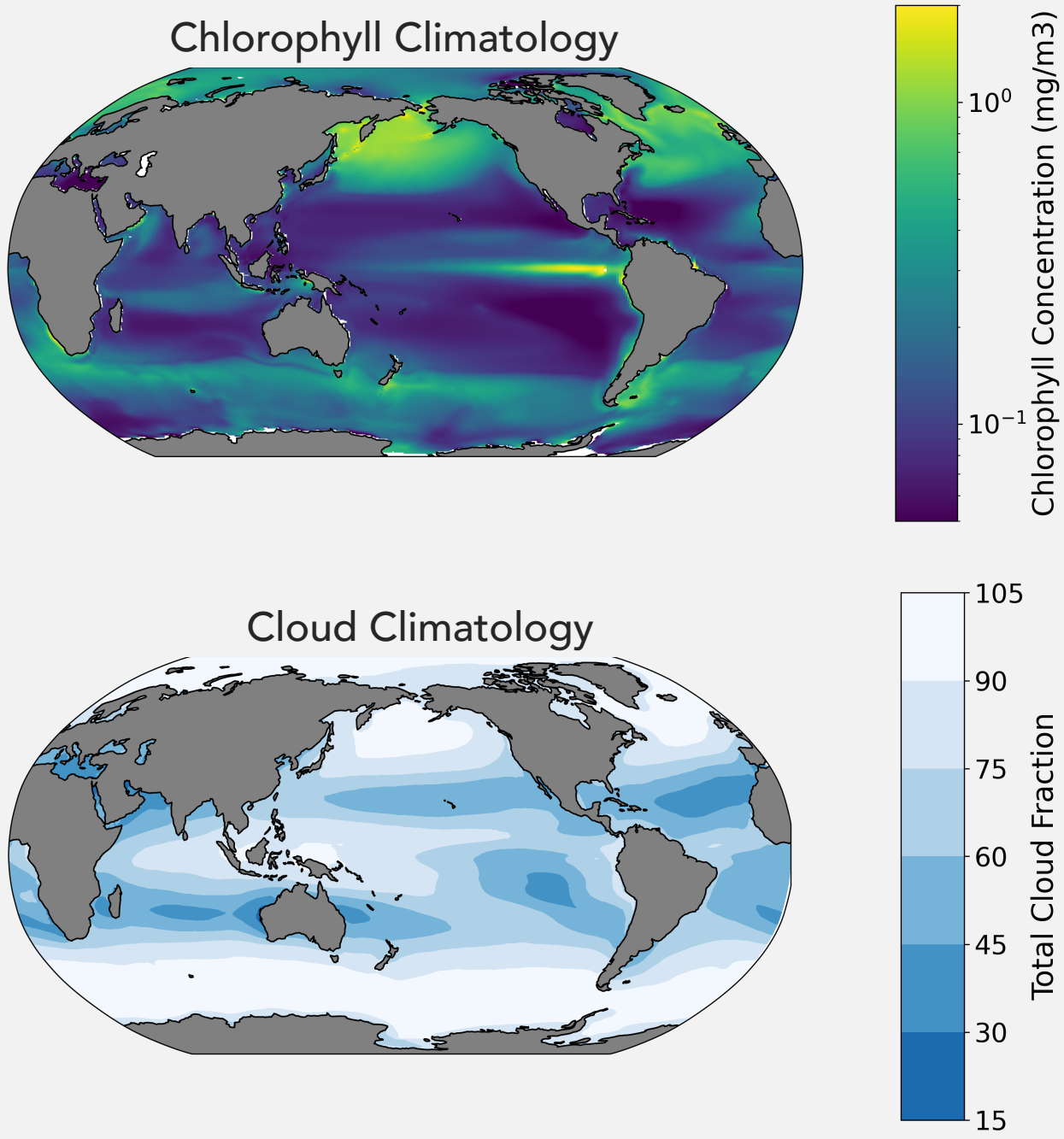
Phytoplankton

- Base of the marine food web
- Responsible for 50% of primary productivity on Earth
- Global abundance estimated through remote sensing of chlorophyll (chl.)



NASA Ocean Color Image Gallery

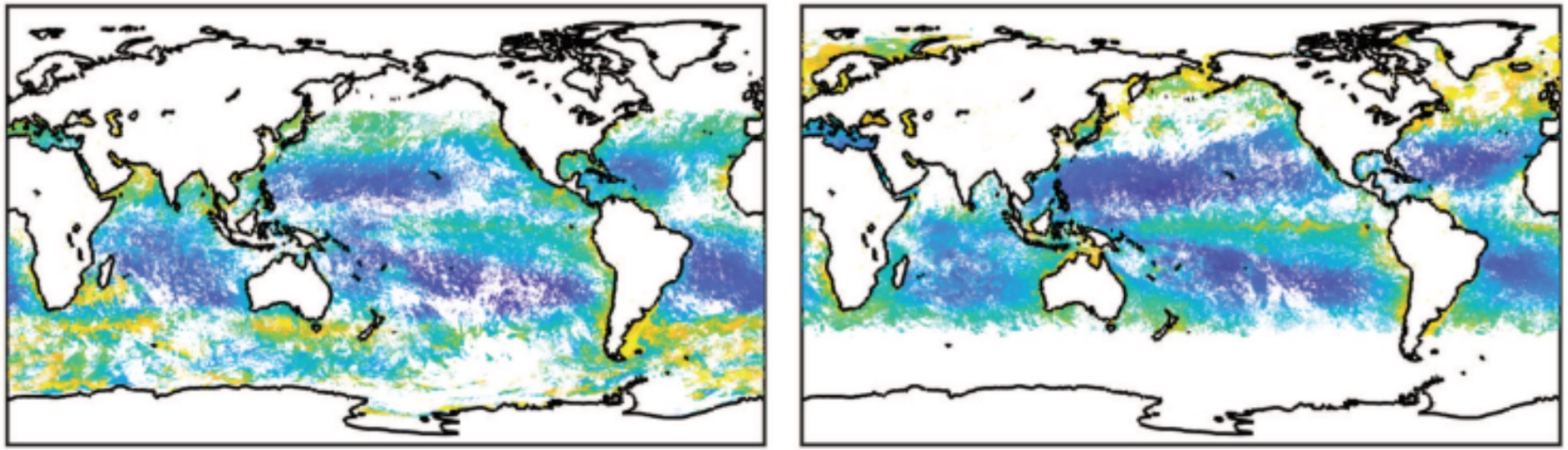
We are unable to reliably detect phytoplankton from satellite observations in the regions where they are most abundant.



Chlorophyll Satellite Observations

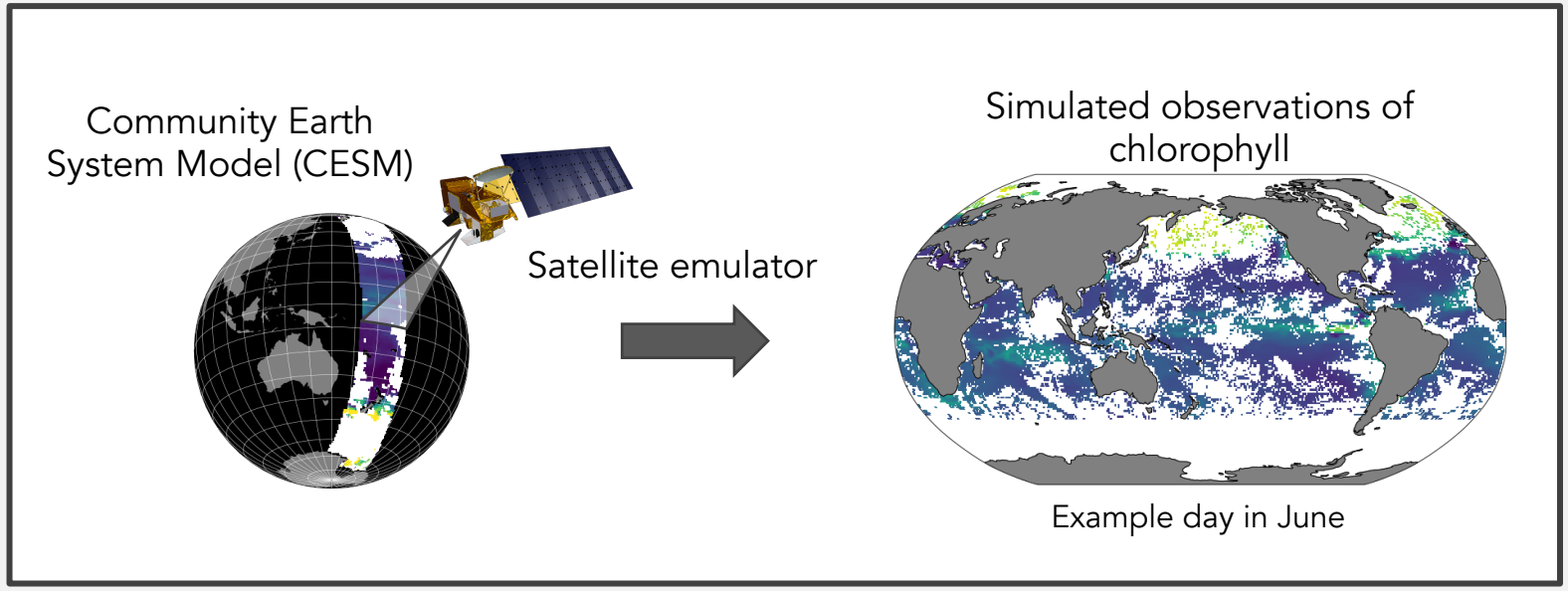
VIIRS Chlorophyll, January 1-8 (2020)

VIIRS Chlorophyll, June 1-8 (2020)



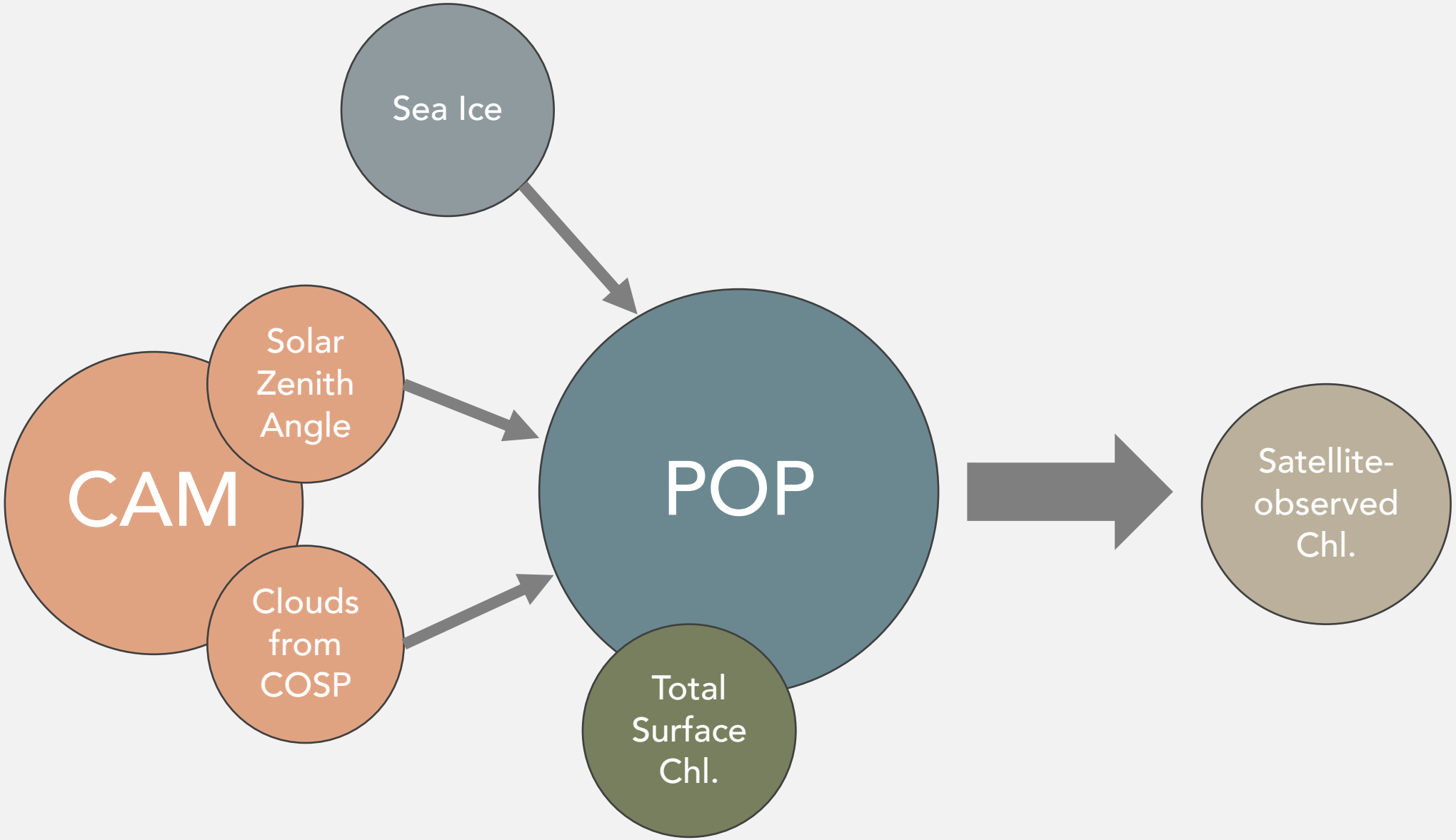
Natural log of the 8-day averaged surface ocean chlorophyll concentration in mg/m^3

Satellite Emulator for Chlorophyll



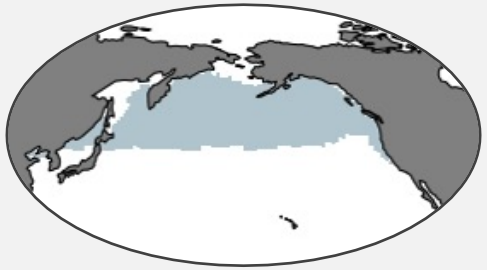
Included in emulator:
- Clouds
- Sunlight
- Sea ice

Not included yet:
- Sun glint
- Sensor viewing angle
- White caps
- Coccolithophores
- Aerosols

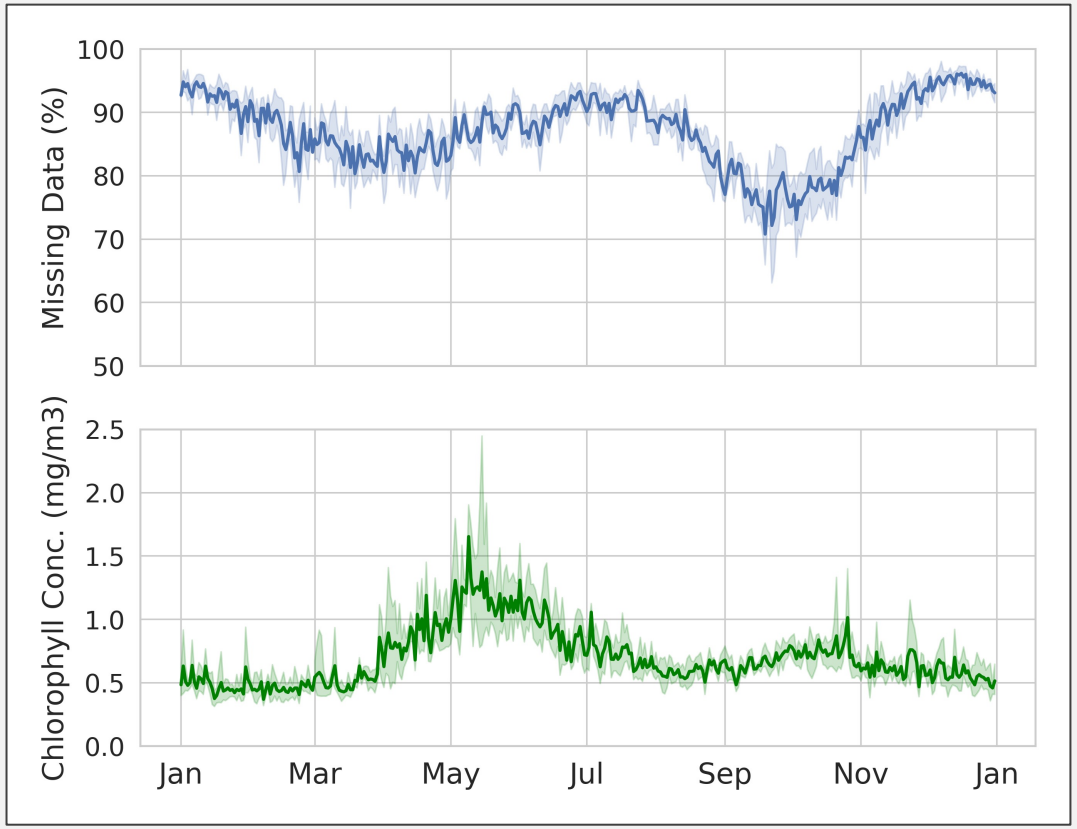

Sea Ice
Solar Zenith Angle
CAM
Clouds from COSP
POP
Total Surface Chl.
Satellite-observed Chl.

CESM 2.2 Setup	
Atmosphere model	CAM6 with COSP enabled
Ocean model	POP2 with MARBL
Component set	B1850
Grid	f09_g17
Run Length	50 years (analyzed the last 30)

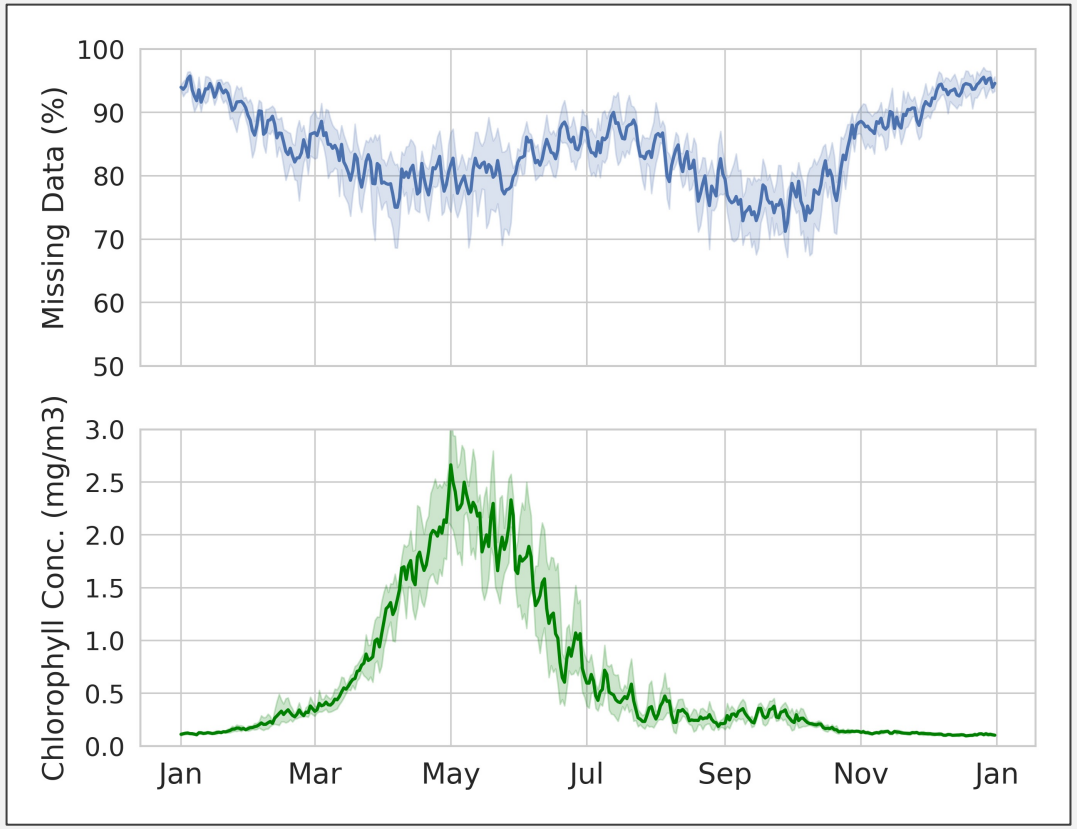
North Pacific Satellite Data Comparison



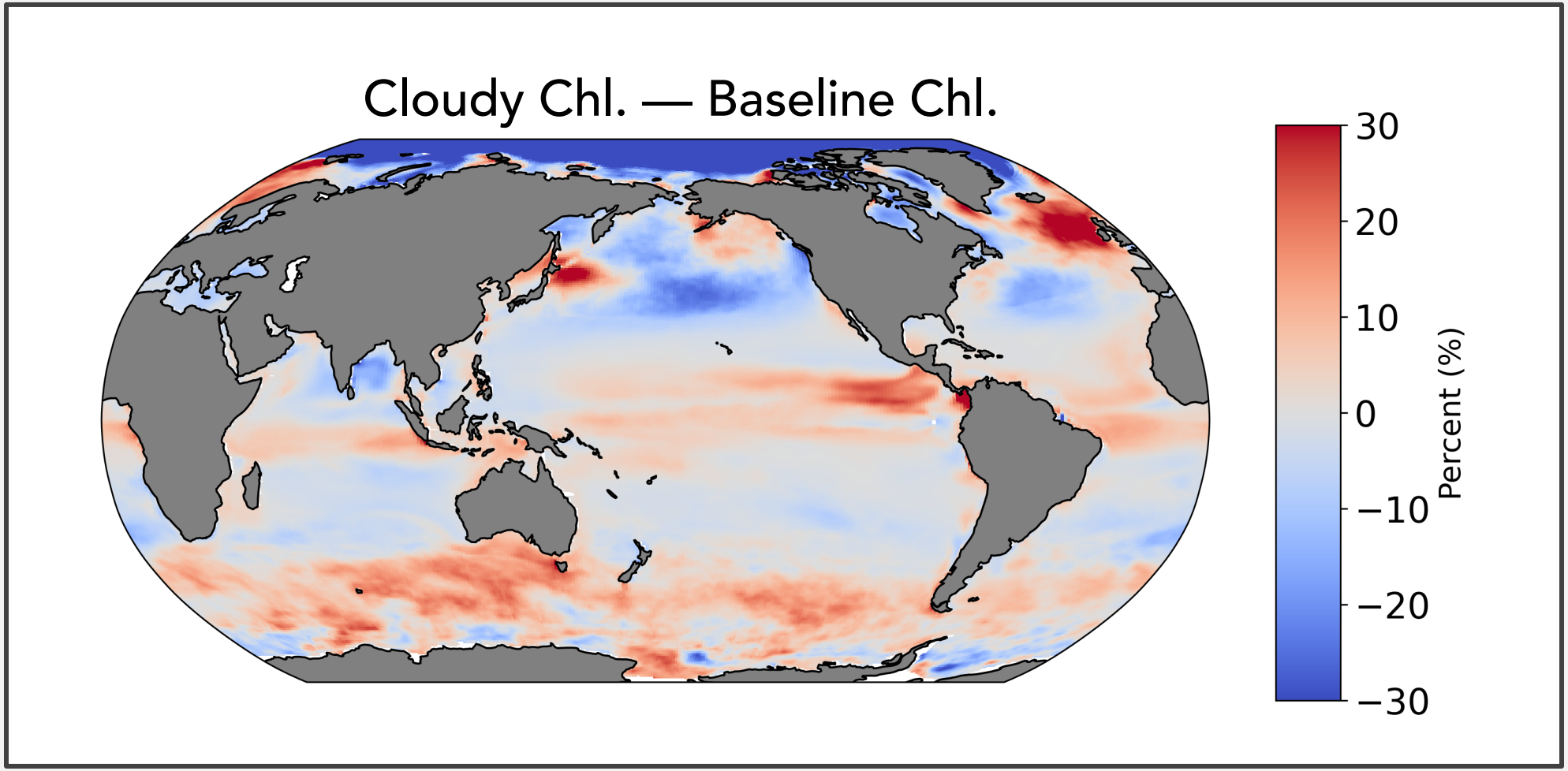
Satellite Data
(MODIS & VIIRS, 2014 - 2019)



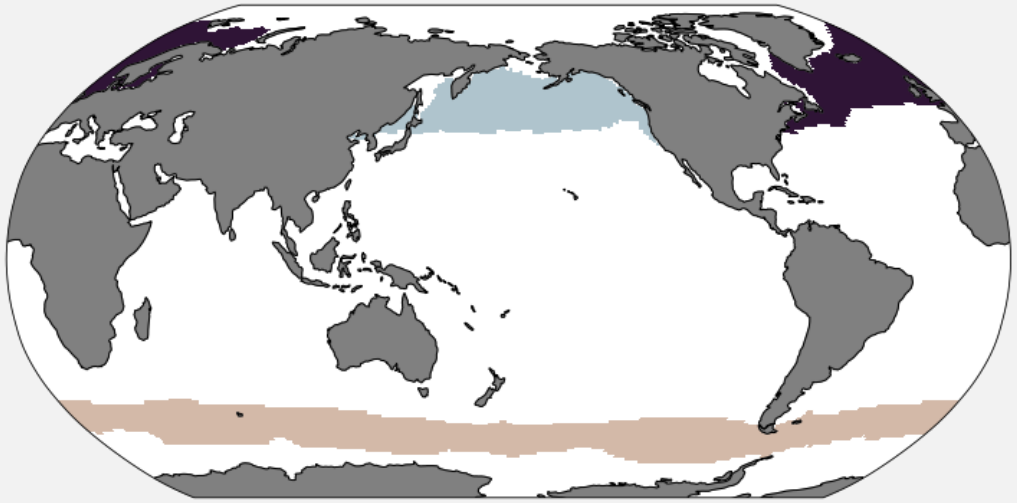
CESM Satellite Emulator
(5 years pre-industrial)



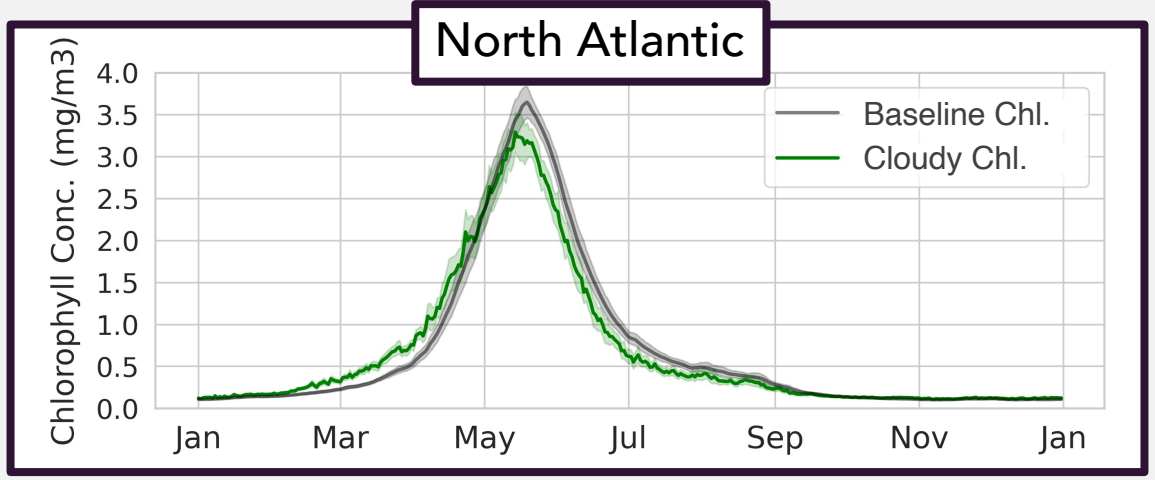
Climatology Differences

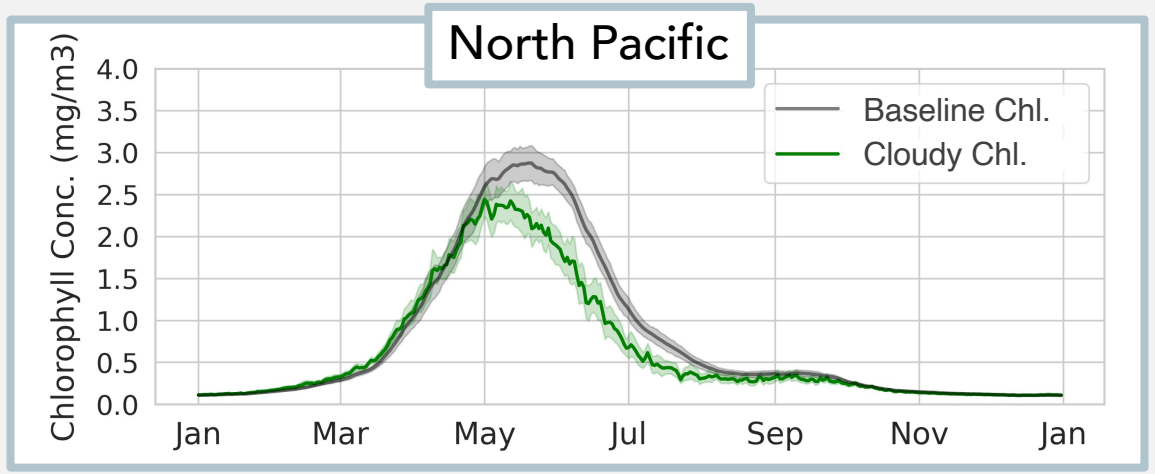


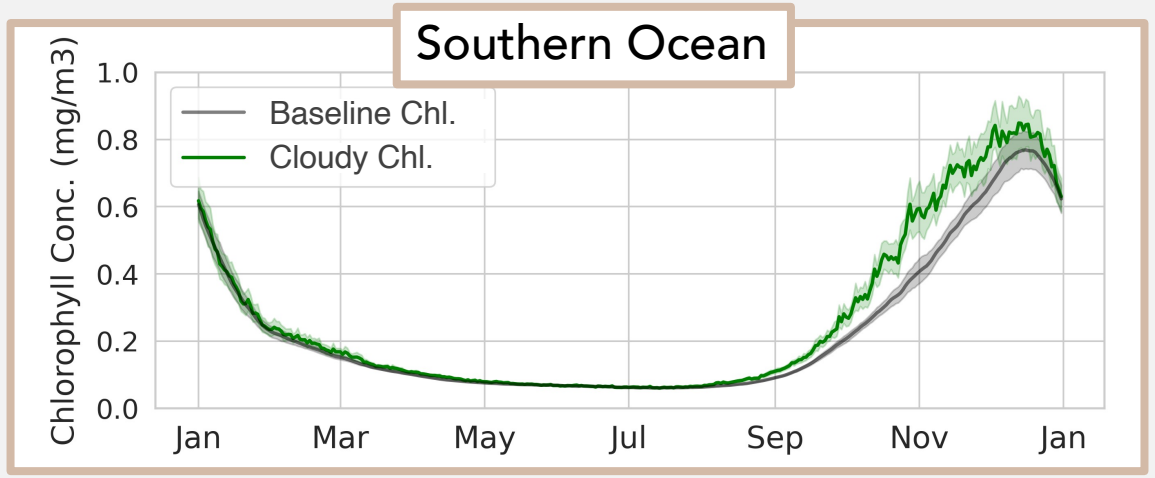
Mean Seasonal Cycle Over Biomes



Biomes from Fay & McKinley 2014



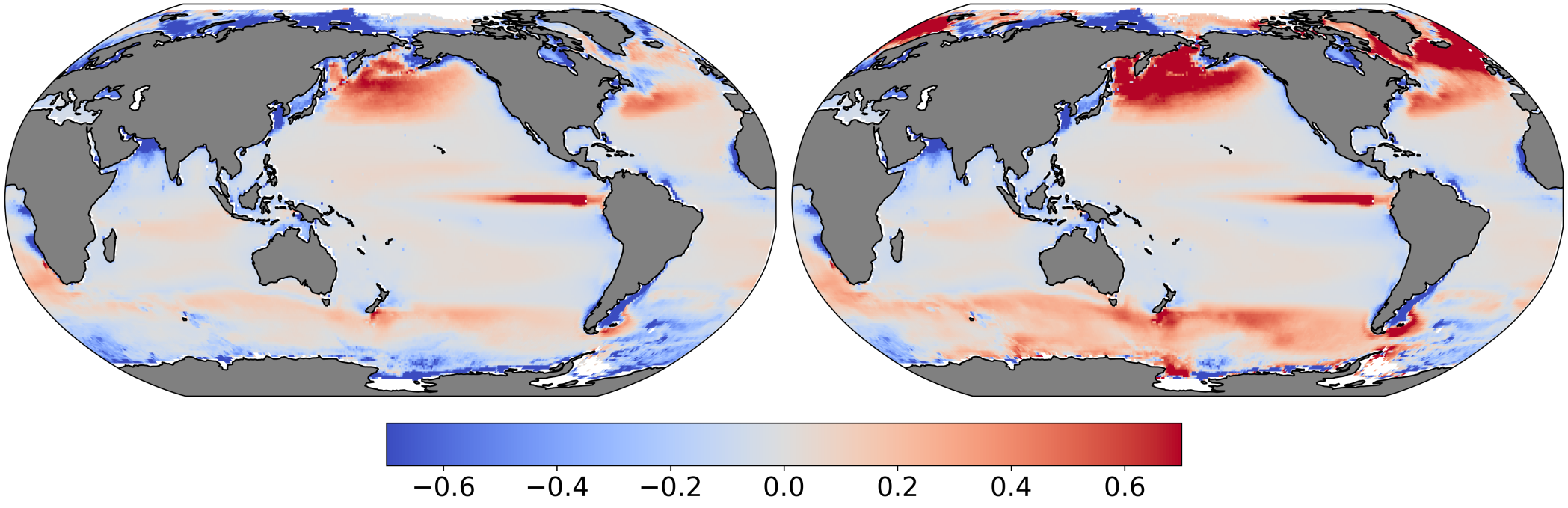




Application: Model Tuning

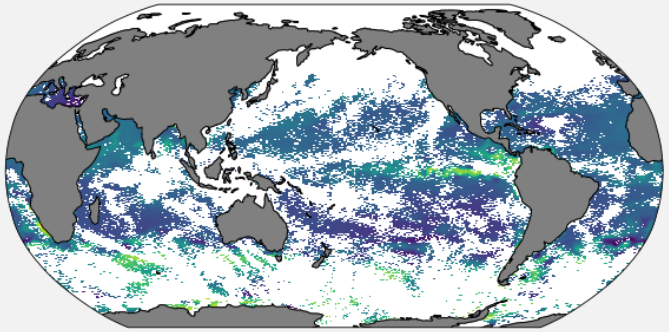
Apparent Bias
(Model - observations)

Actual Bias
(Simulated observations - observations)



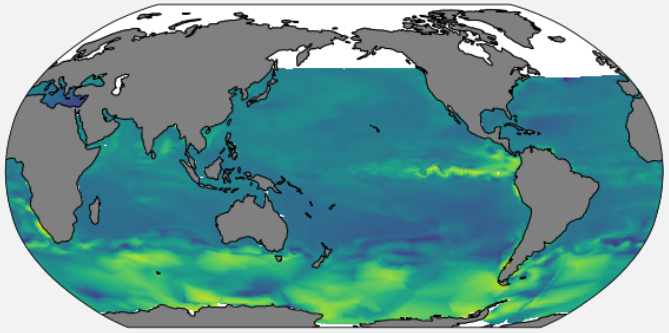
Application: Gap-filling Testbed

Simulated Observations

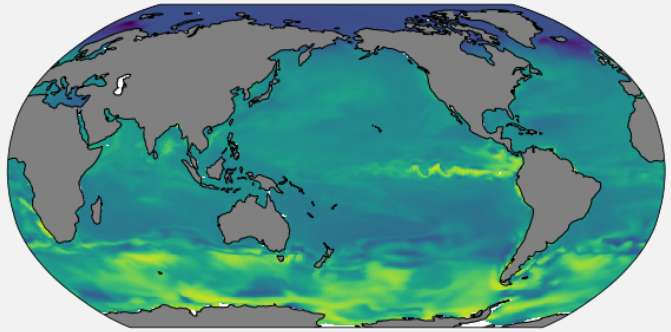


Fill Data Gaps
(linear interpolation, random forest, neural networks, etc.)

Interpolated Result



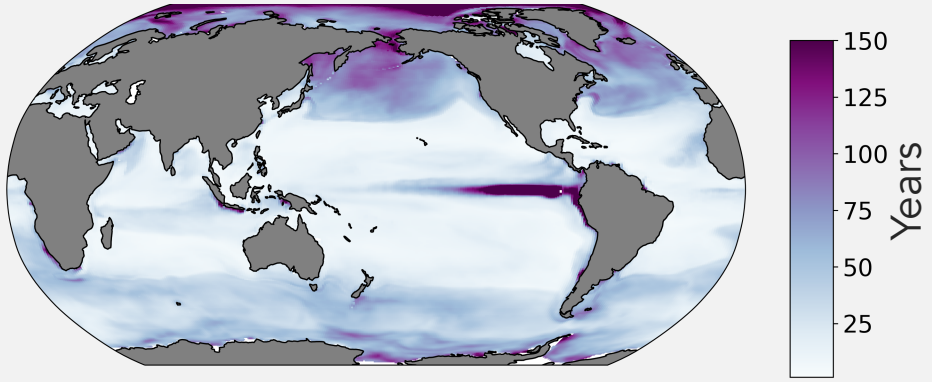
Model Truth



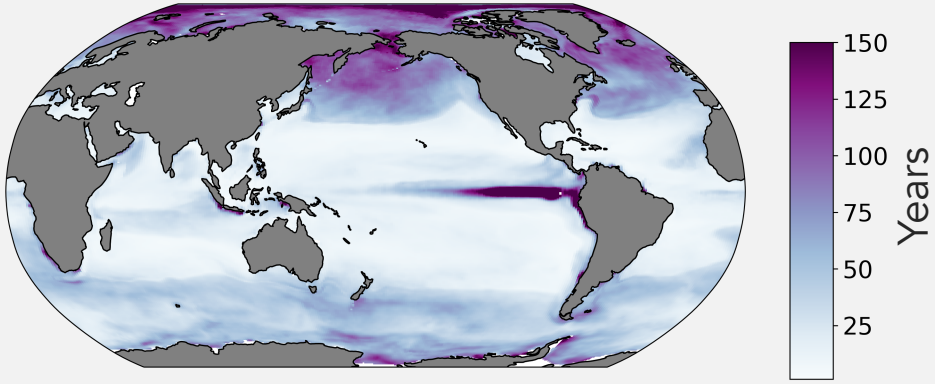
Statistically Compare

Application: Trend Emergence

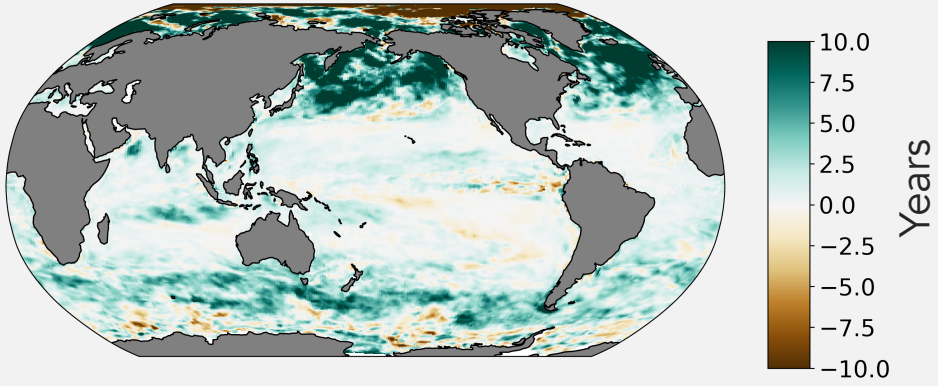
Time to Emergence:
Baseline Chl.



Time to Emergence:
Cloudy Chl.

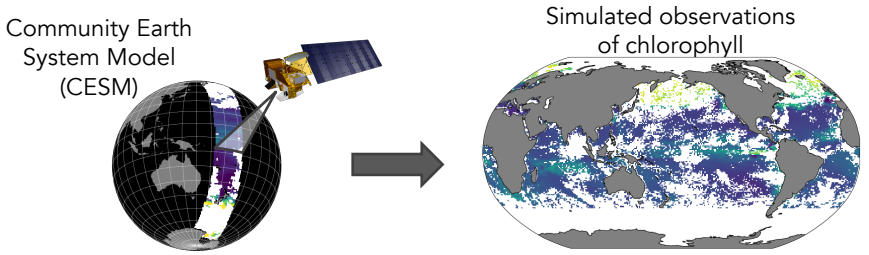


Difference:
Cloudy Chl. — Baseline Chl.

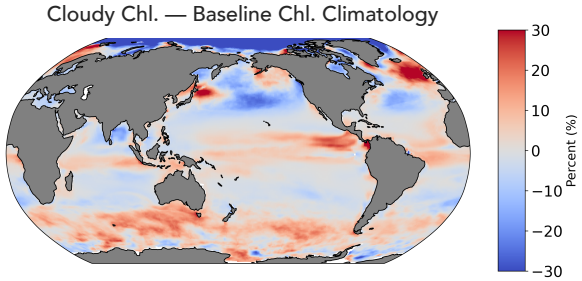


Conclusions:

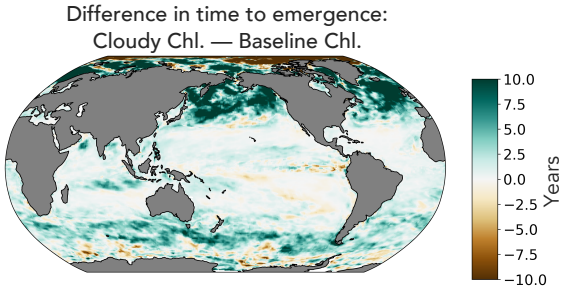
We developed a satellite emulator for ocean chlorophyll in CESM



Initial results indicate that the chlorophyll climatology and mean seasonal cycles are biased due to missing data from cloud cover



Future applications:
model tuning, gap-filling, trend emergence

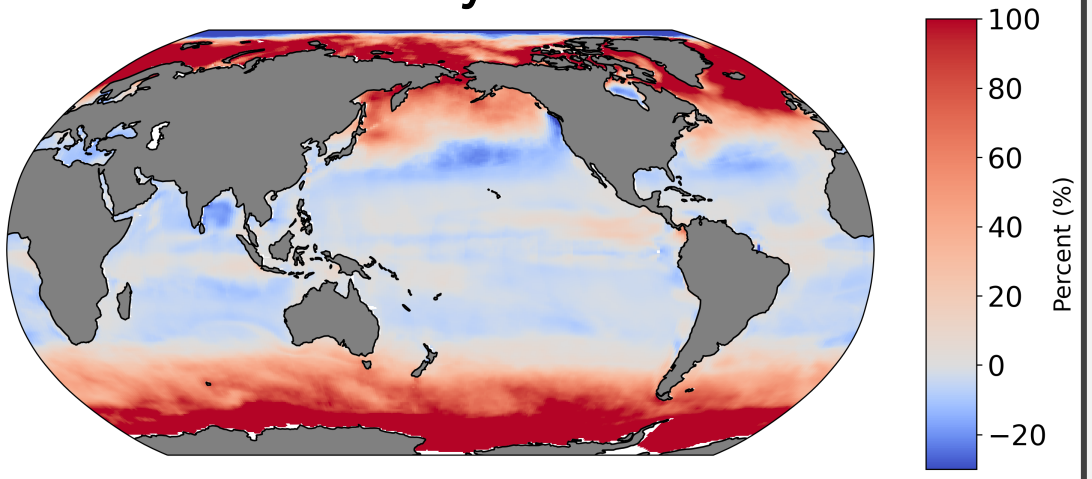


Thank you! Contact Info: genevieve.clow@colorado.edu

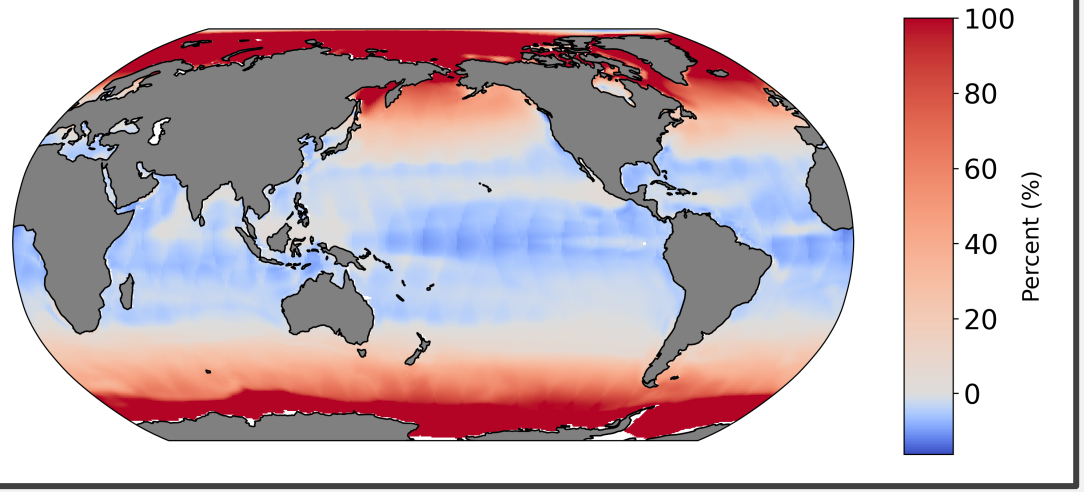
EXTRA SLIDES

Chlorophyll Climatology Differences

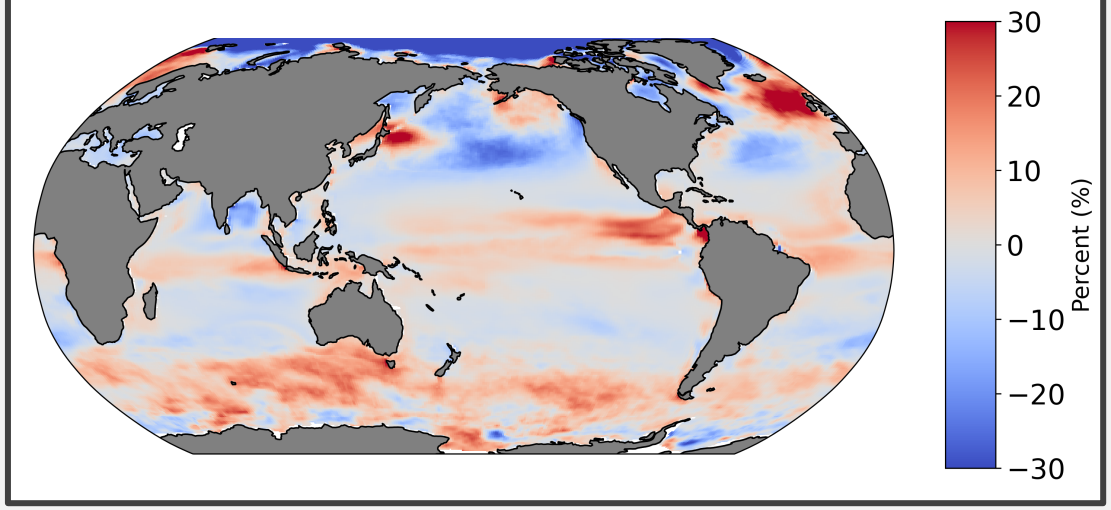
Total bias in simulated observations:
Cloudy Chl – Total



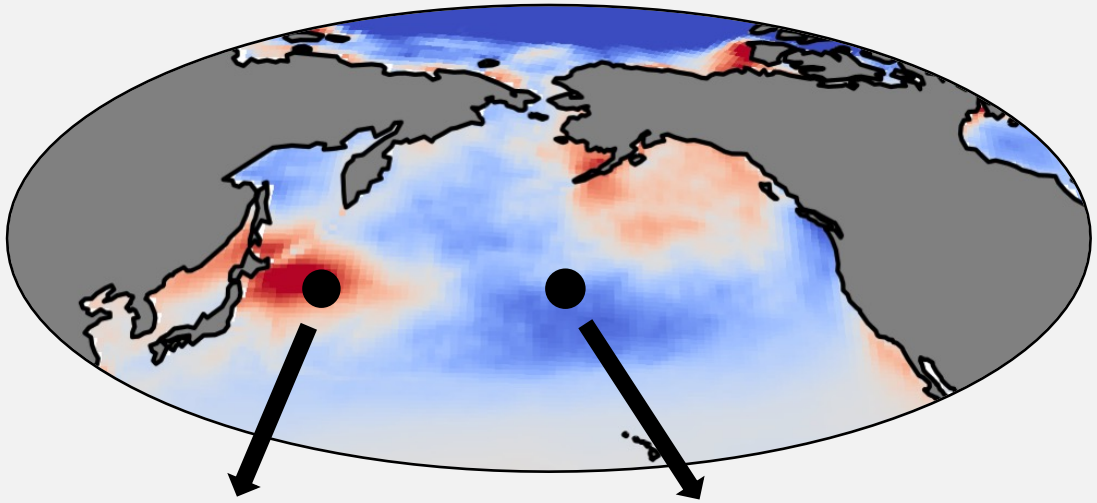
Bias due to daylight-only sampling and sea ice:
Baseline – Total



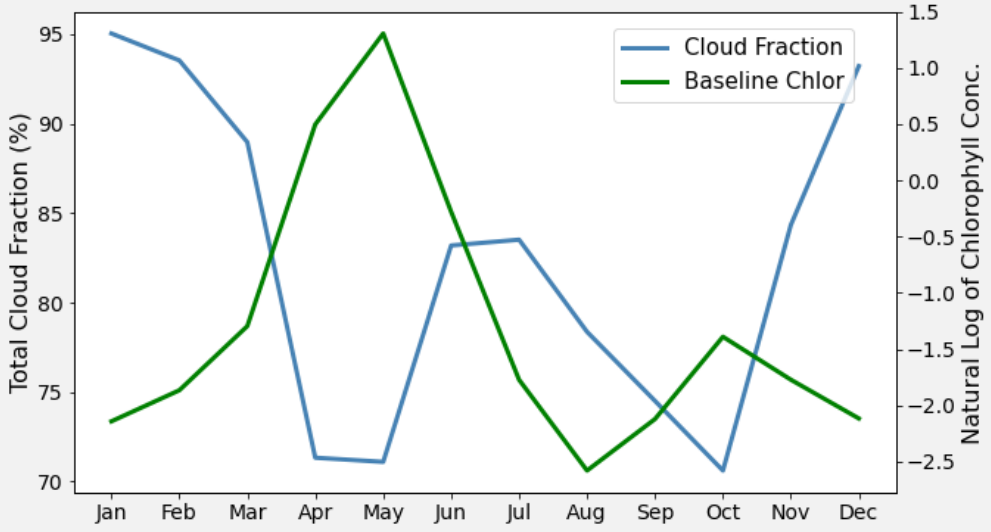
Bias due to cloud cover:
Cloudy Chl – Baseline



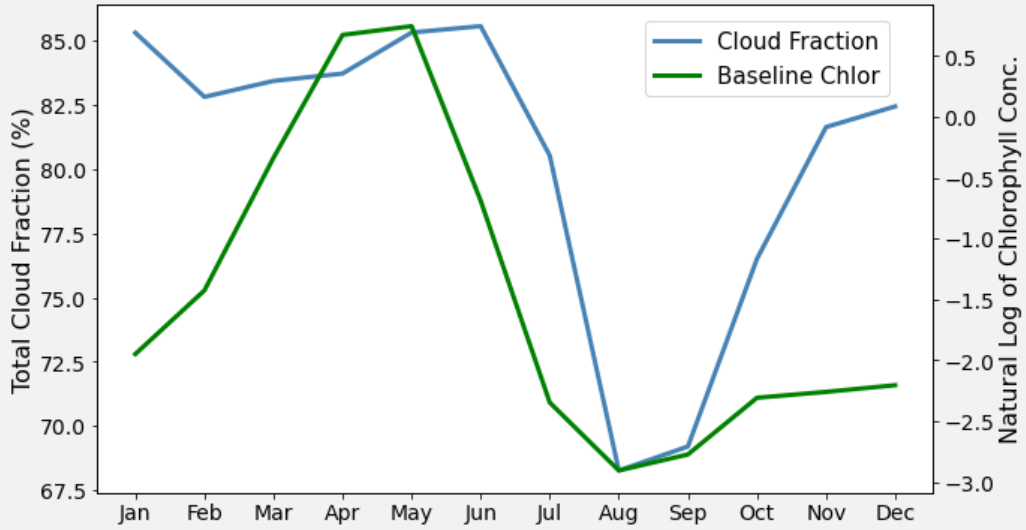
Differences in Seasonal Cycle



High chlor, low clouds = overestimation

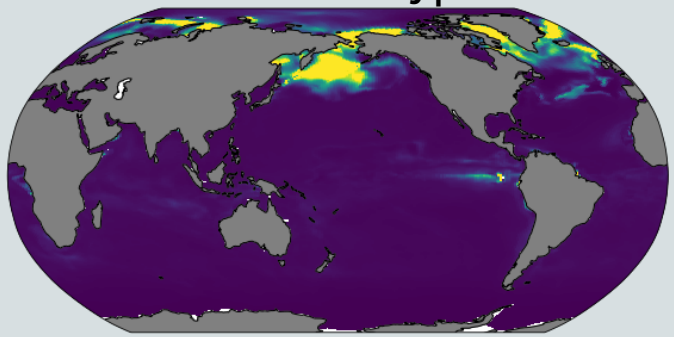


High chlor, high clouds = underestimation

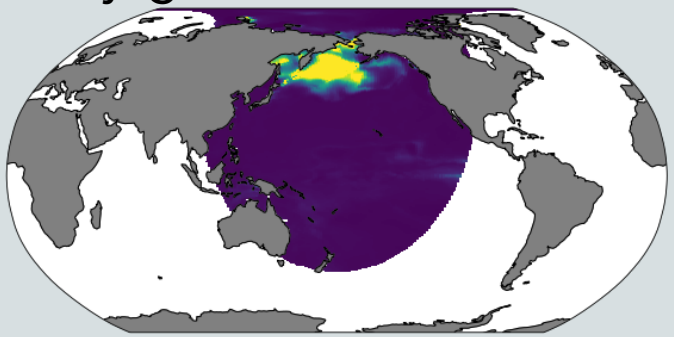


New Hourly Model Outputs

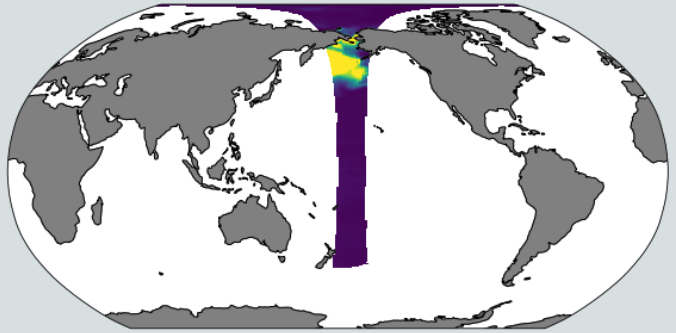
Total Chlorophyll (Surface):
Sum over all phytoplankton functional types



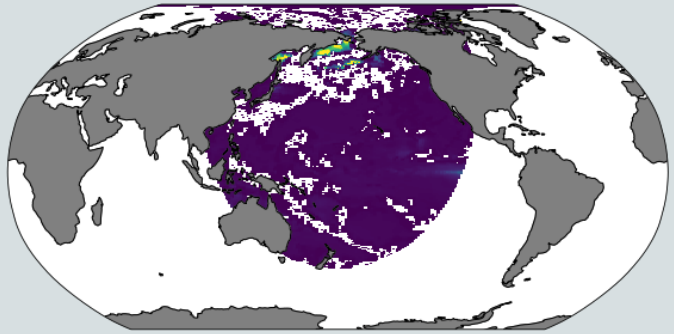
Baseline Chlorophyll:
Total chlorophyll with daylight and sea ice masks



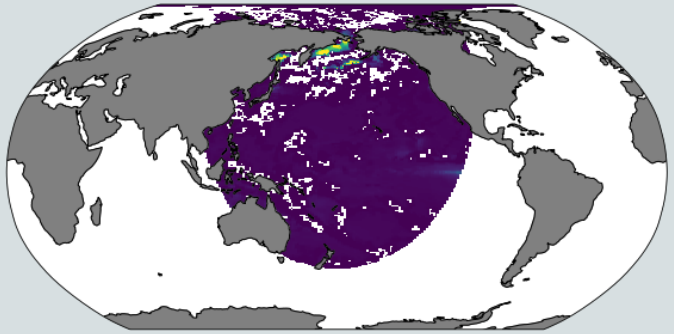
Baseline Chlorophyll with Aqua MODIS swath:



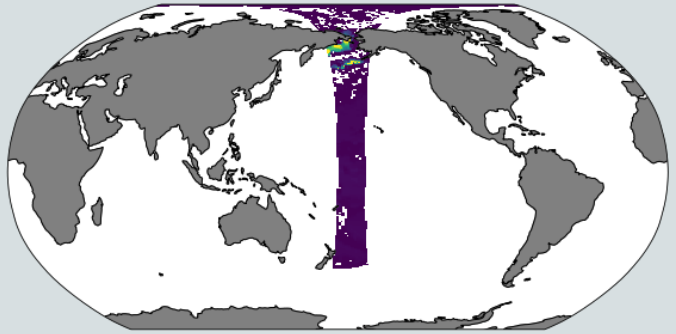
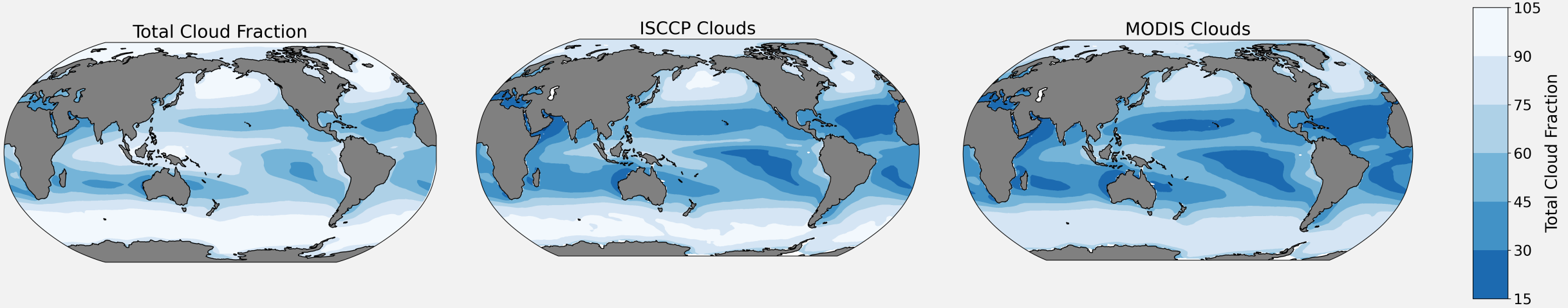
ISCCP Chlorophyll:
Baseline with ISCCP clouds used for weighting



MODIS Chlorophyll:
Baseline with MODIS clouds used for weighting



MODIS Chlorophyll with swath:



Cloud Comparison