MODIS Measurements of Passive Fluorescence: Comparisons with Theoretical Values and Field Data

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The role of ecosystem structure in the flow of energy and elements

"That swarm of locusts"

In 1889 G.T. Garruthers described in *Nature* a swarm of locusts over the Red Sea and derived a figure of 24 quadrillion locusts equivalent to 43 billion tons.

Thirty years later Vladimir Vernadsky wrote in his book *La Geochimie:*

"expressed in terms of chemical elements and in metric tons, may be seen as analogical to a rock formation, or more precisely: to a moving rock formation endowed with free energy"

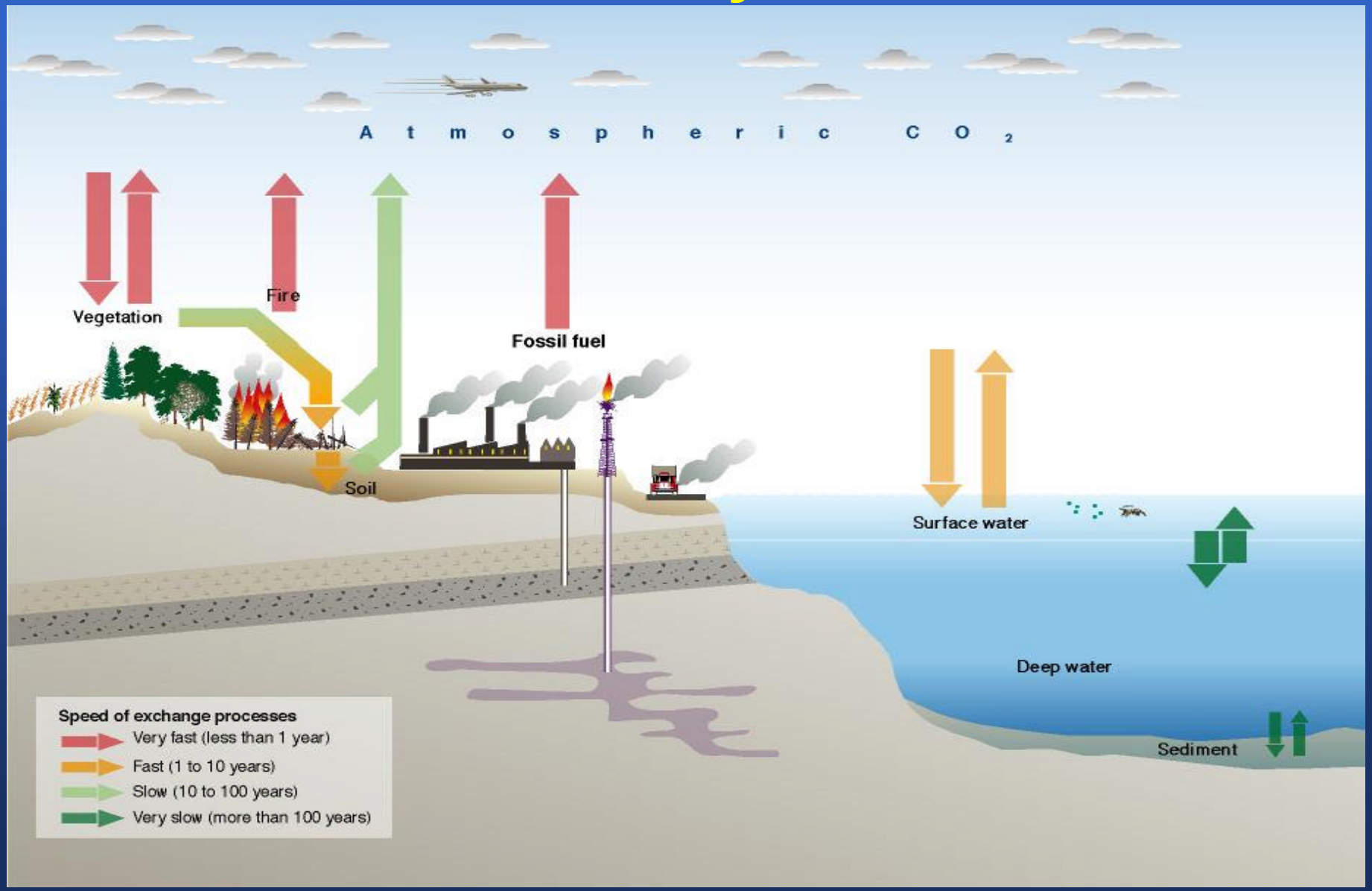
Two major roles of organisms in biogeochemical cycles:

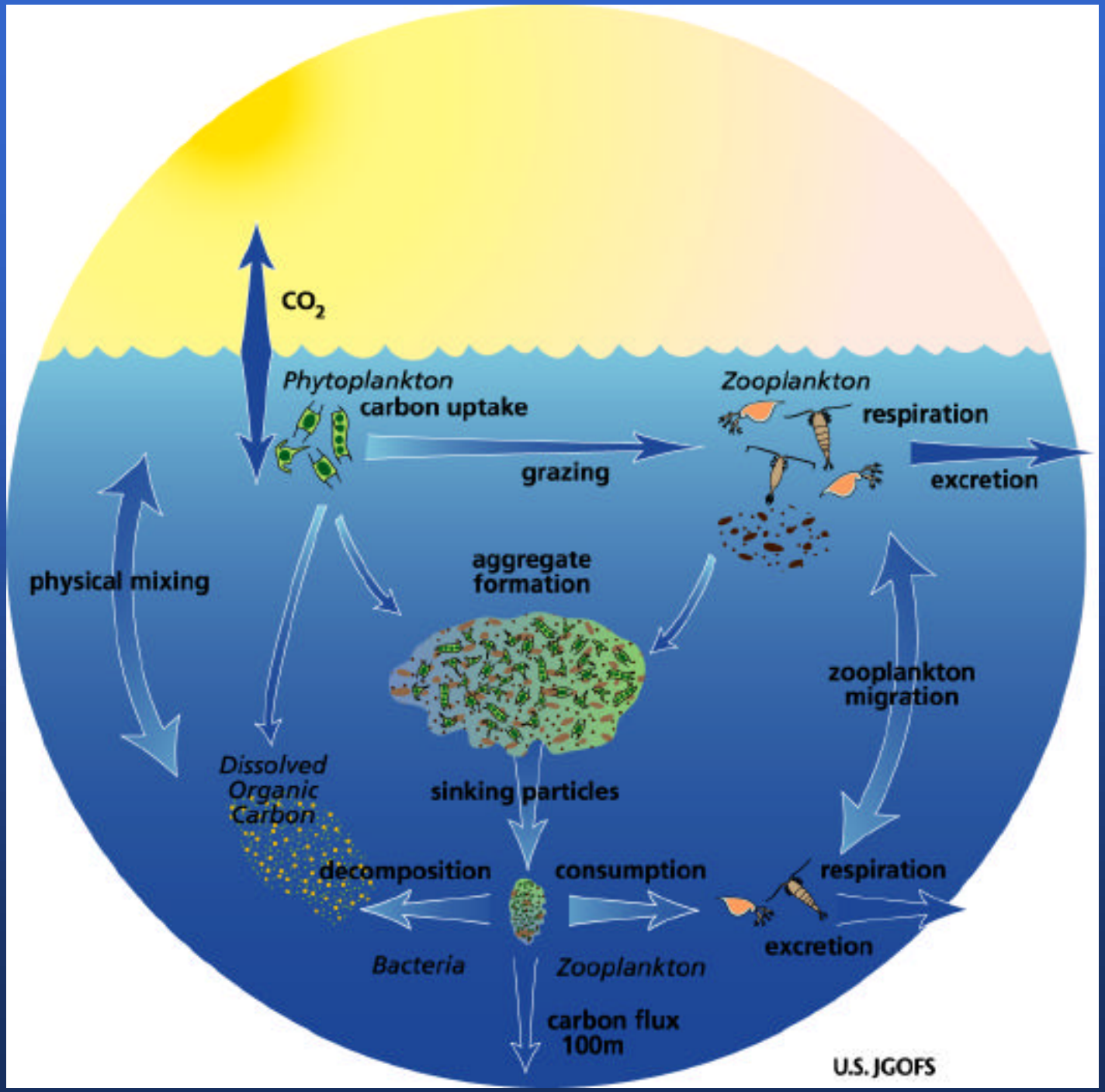
- Storage of energy and elements
- Mobilization of stored elements and energy in space
  - The interaction between different types of organisms at different trophic levels and the environment (ecosystem structure) will influence how bioelements and organic energy are distributed and stored in the biosphere.
  - In turn, the availability of bioelements and energy, as well as the rate of perturbation of the ecosystem will affect the ecosystem structure.
  - Interaction of ecology and physics

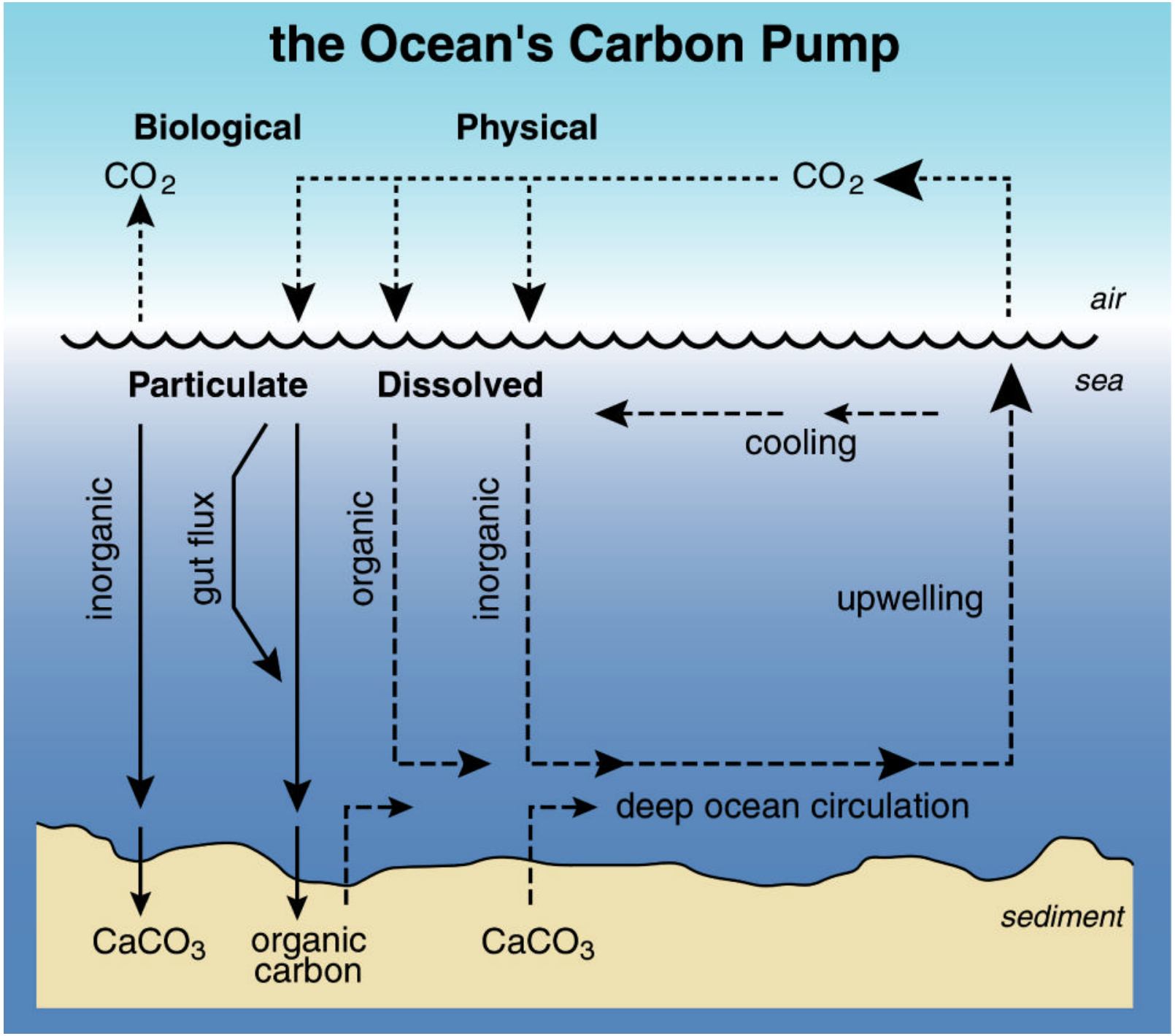
Variability and Response

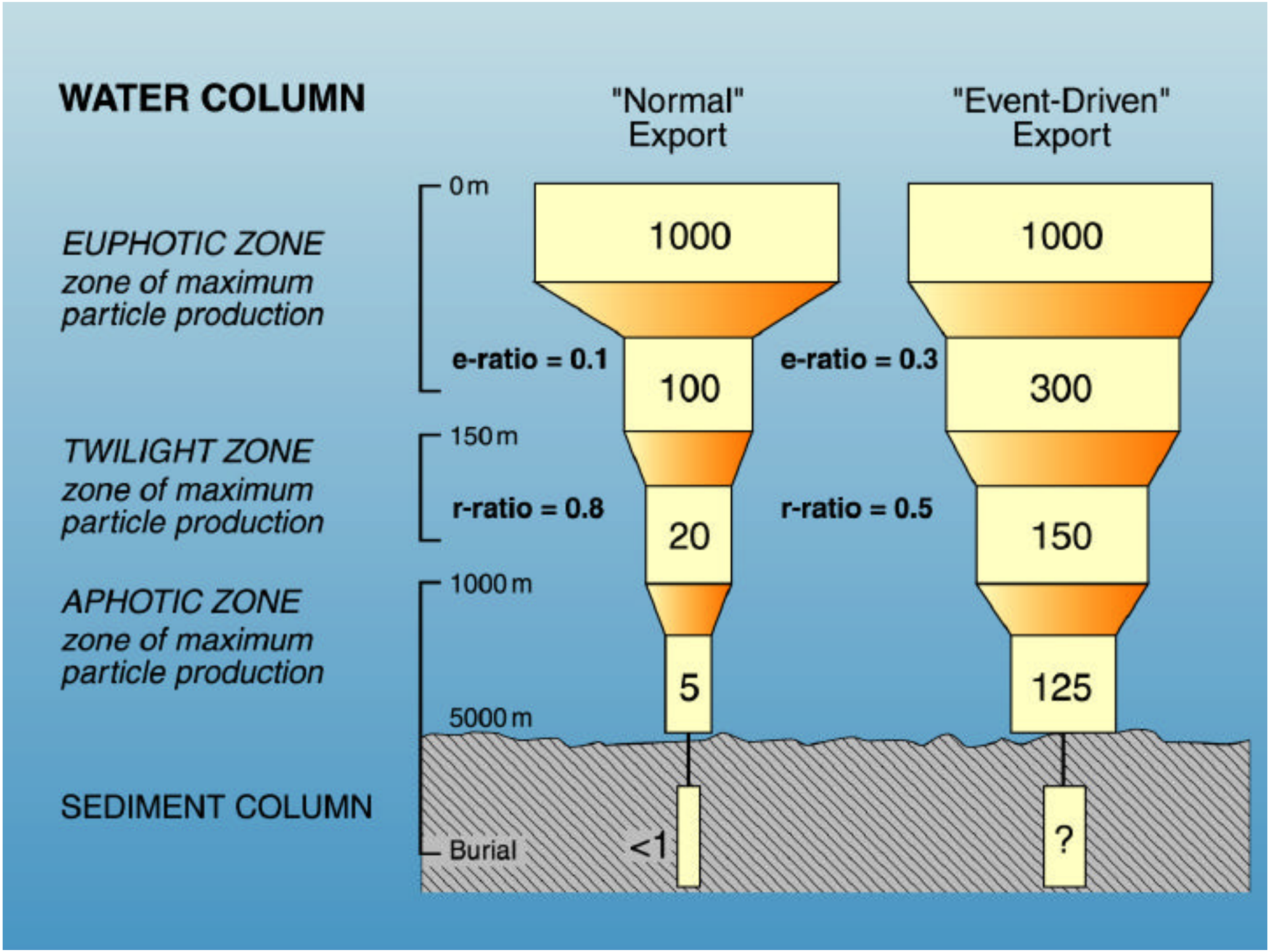
- How will the ocean's role in carbon cycling change in response to changes in climate?
  - Changes in circulation and temperature
  - Shifts in ecosystem structure and carbon export

There are fast and slow processes in the carbon cycle




CO_2
Phytoplankton
carbon uptake
Zooplankton
respiration
grazing
excretion
physical mixing
aggregate
formation
zooplankton
migration
Dissolved
Organic
Carbon
sinking particles
decomposition
consumption
respiration
excretion
Bacteria
Zooplankton
carbon flux
100m
U.S. JGOFS


the Ocean's Carbon Pump
Biological
Physical
CO_2
CO_2
air
sea
Particulate
Dissolved
cooling
inorganic
gut flux
organic
inorganic
upwelling
deep ocean circulation
$CaCO_3$
organic carbon
$CaCO_3$
sediment


WATER COLUMN
"Normal" Export
"Event-Driven" Export
0 m
EUPHOTIC ZONE
zone of maximum particle production
1000
1000
e-ratio = 0.1
100
e-ratio = 0.3
300
150 m
TWILIGHT ZONE
zone of maximum particle production
r-ratio = 0.8
20
r-ratio = 0.5
150
1000 m
APHOTIC ZONE
zone of maximum particle production
5
125
5000 m
SEDIMENT COLUMN
Burial
<1
?

Understanding the contribution of oceanic biology to carbon sequestration (biological pump) requires to:

- Determine the magnitude of Primary Productivity at regional and global scales.
- Characterize the mesoscale variability in ecosystem structure and how this variability affects the fate of organic matter.

What is the Role of MODIS Fluorescence Measurements?

- Improve estimates of primary productivity on mesoscales
- Detect changes in the light/chlorophyll response of phytoplankton
- Determine relative impacts of changes in physical environment versus changes in ecosystem structure

Productivity Algorithms

- $PP = [chl] \times (PAR \times a^*) \times \Phi_p$

  where PP = Primary Productivity

  [chl] = chlorophyll concentration

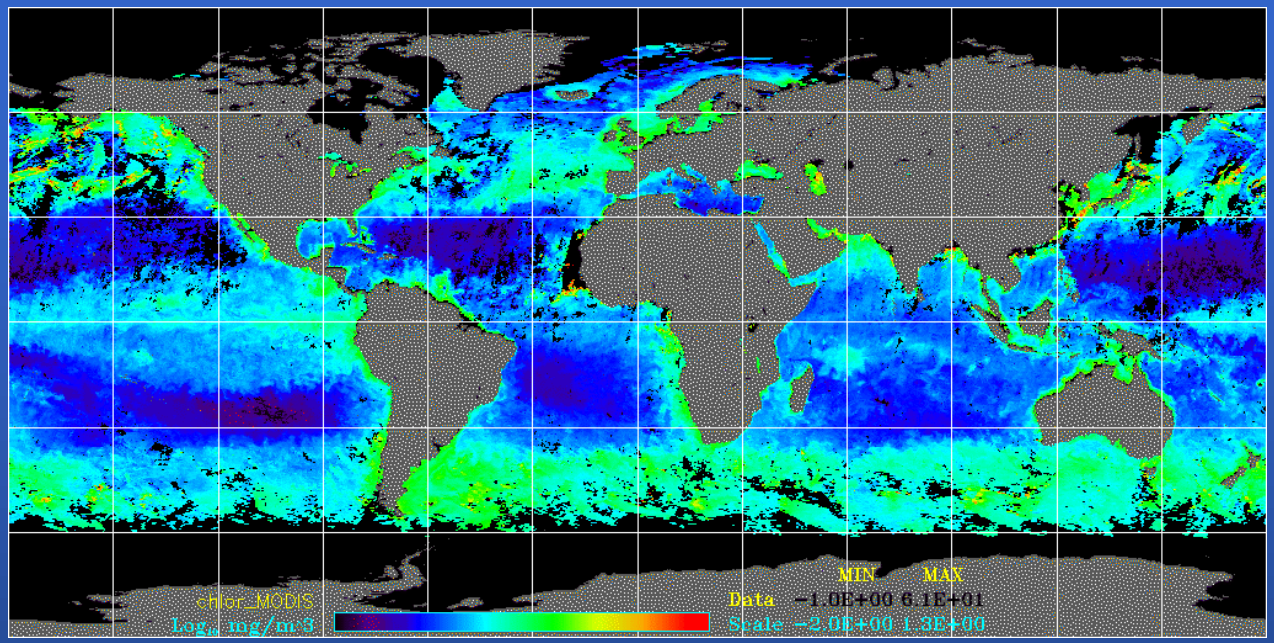
  PAR = photosynthetically available radiation

  a^* = chlorophyll specific absorption

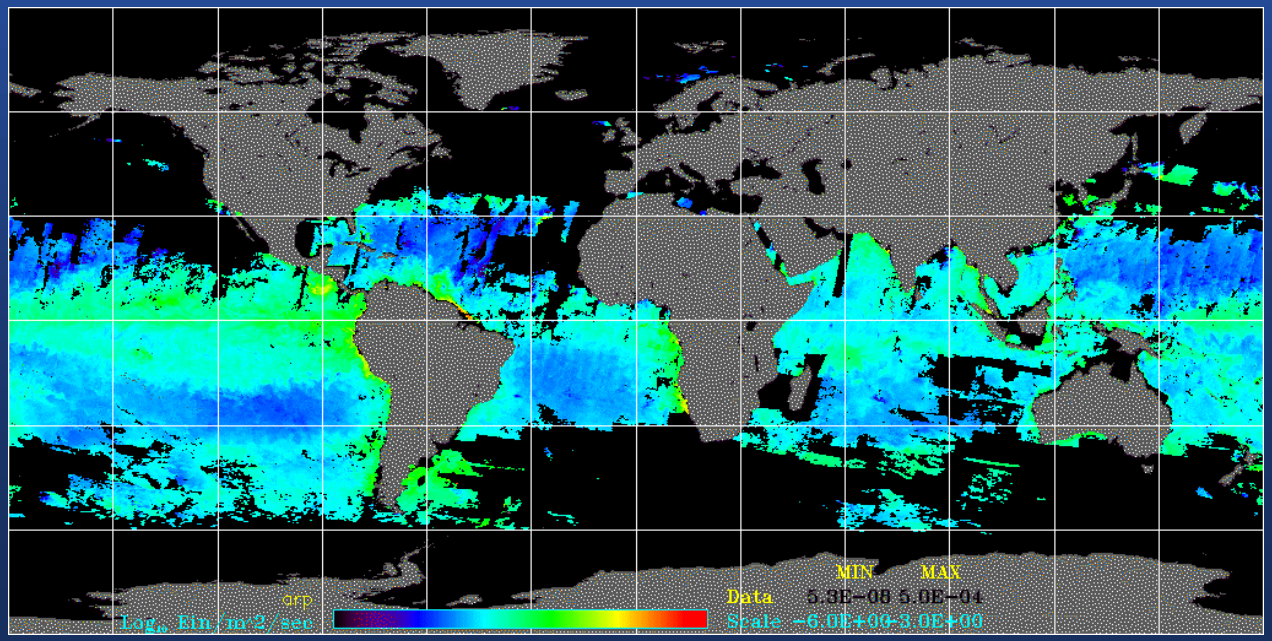
  ϕ_p = photosynthesis quantum yield

$[chl] \times (PAR \times a^*)$ = ARP (Absorbed Radiation by Phytoplankton)

Goddard DACC weekly declouded 36 km starting 04/07/2001 (Quality=0 L2 V 3.2.1)



MODIS chl

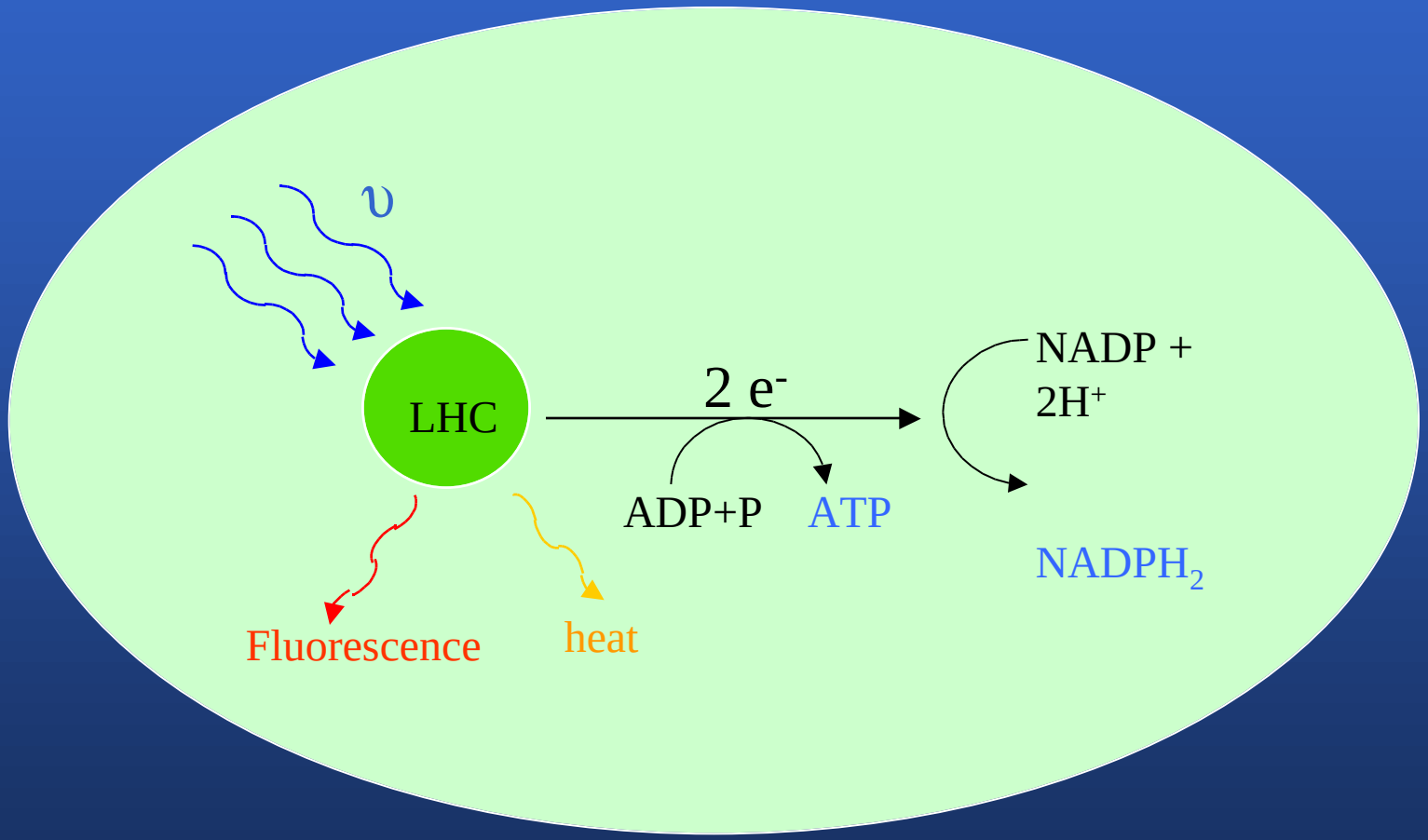


MODIS ARP

Estimates of Primary Productivity

Study	GLOBAL
Longhurst et al. (1995)	45-50 Pg C/yr
Behrenfeld and Falkowski (1997)	48.5
Martin et al. (1987)	51
Berger (1989)	27.0
Walsh (1988)	29.7

Light Harvesting and Fluorescence



$$\Phi_p + \Phi_f + \Phi_h = 1$$

Fluorescence and Productivity

-

where F = fluorescence

[chl] = chlorophyll concentration

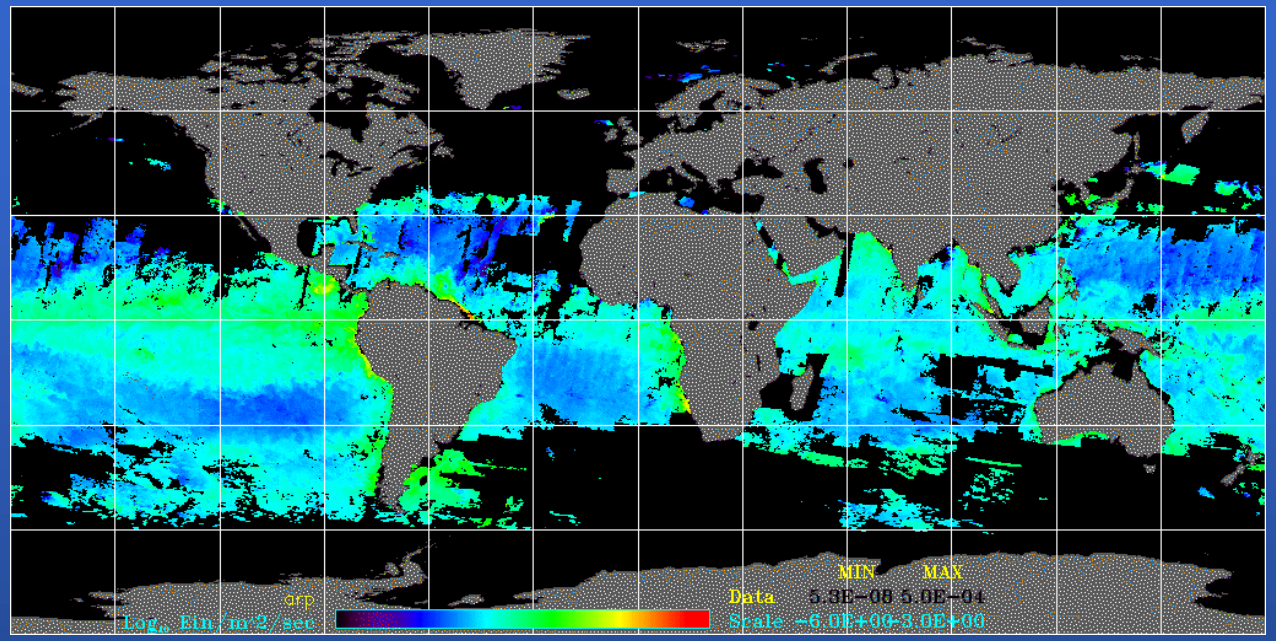
PAR = photosynthetically available radiation

a^* = chlorophyll specific absorption

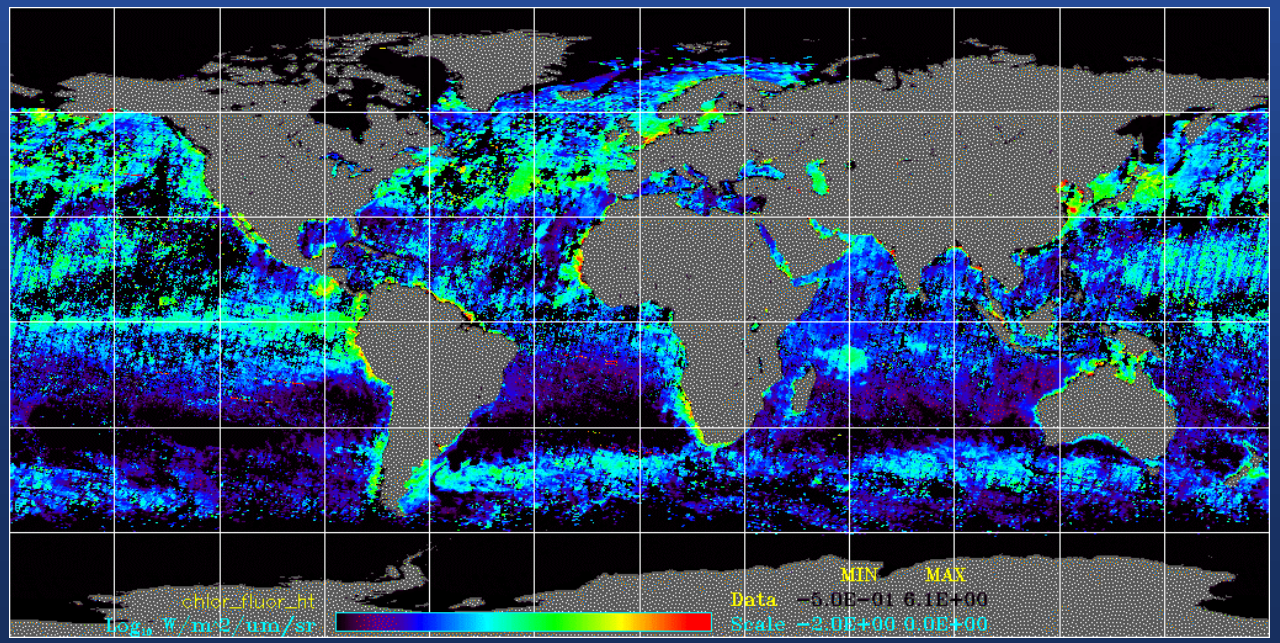
ϕ_F = fluorescence quantum yield

- We can rearrange as F/ARP to estimate ϕ_F

Goddard DACC weekly declouded 36 km starting 04/07/2001 (Quality=0 L2 V 3.2.1)



MODIS ARP



MODIS FLH

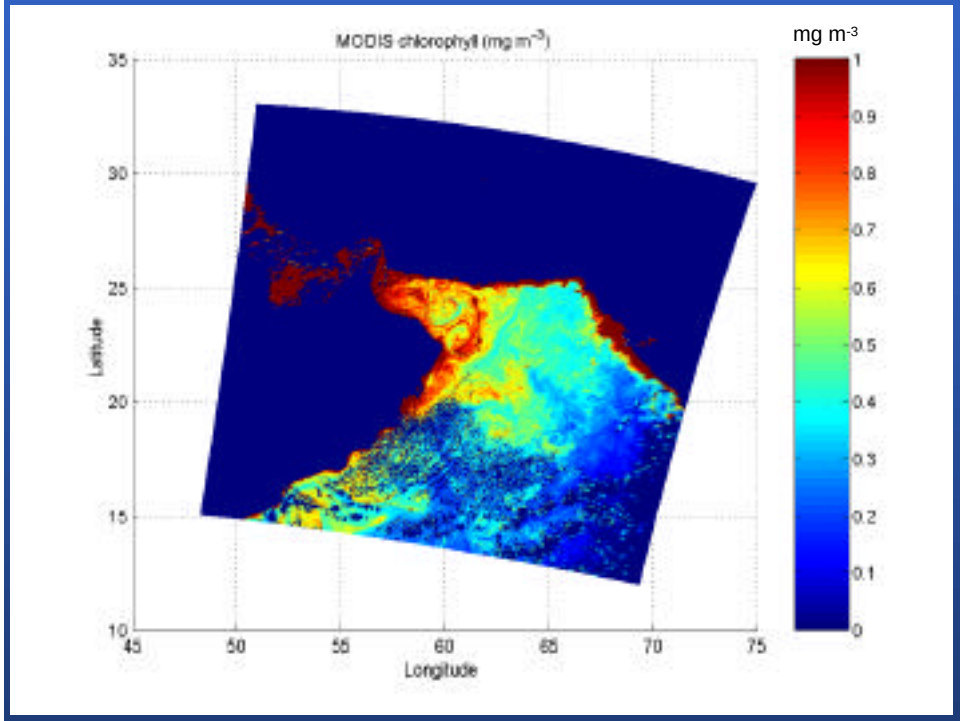
How do we validate FLH & CFE?

- Theoretical approach
  - Analyses of covariance between different MODIS products used in the generation of CFE
  - Based on physiological principles
  - Based on historical field observations
- Empirical approach
  - Field observations from different platforms
  - Concomitant physiological observations

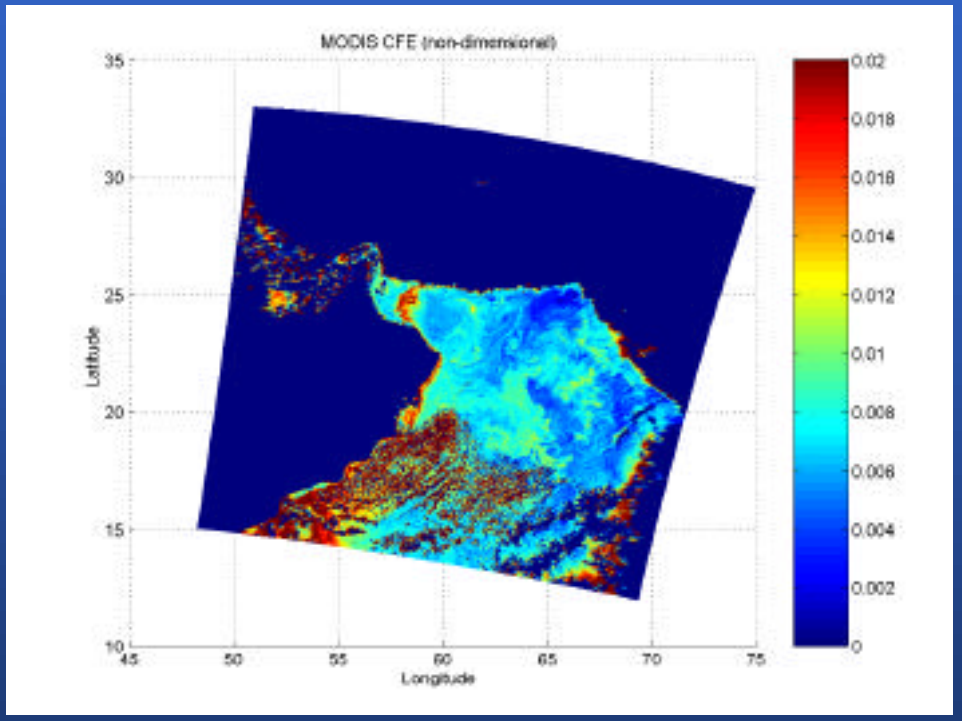
However:

- FLH and CFE are very different MODIS products in terms of validation.
  - FLH is a nLw at 678 nm after baseline correction
  - CFE is a proxy for Φ_f (a physiological parameter) that requires the previous validation of ARP.
  - Further use of Φ_f to infer Φ_p requires the characterization of the variability in energy distribution within the photosystem

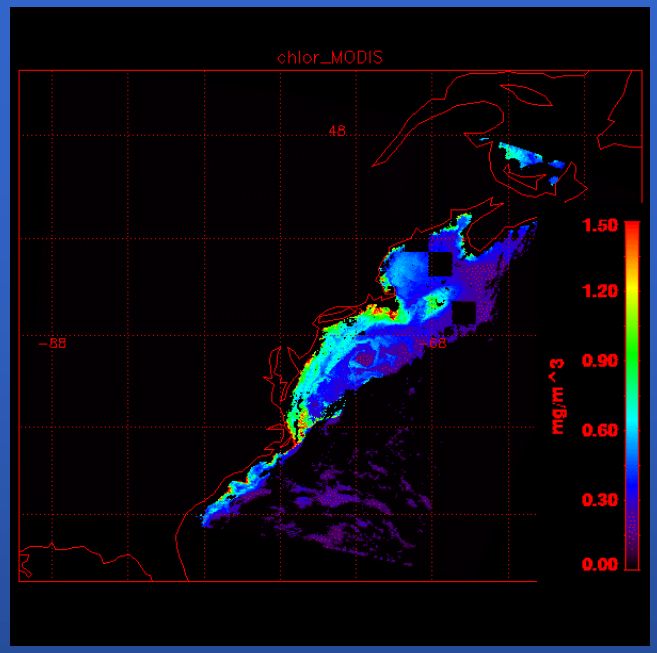
MODIS Chl



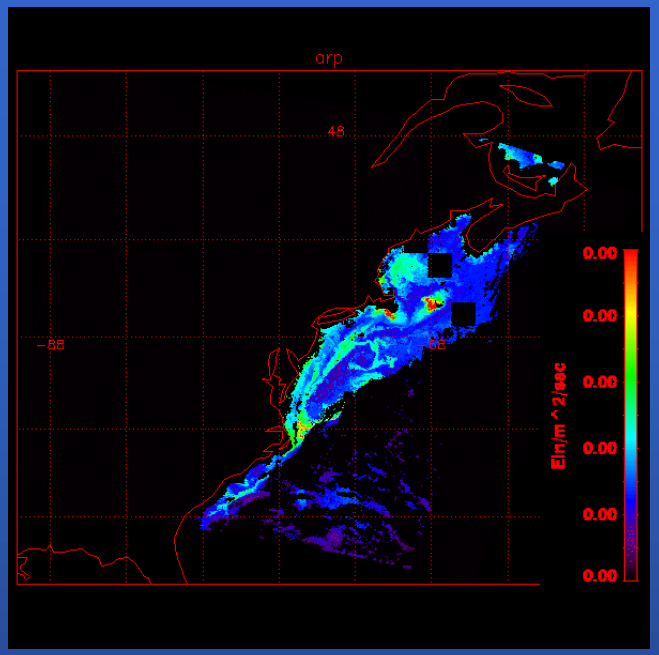
MODIS CFE



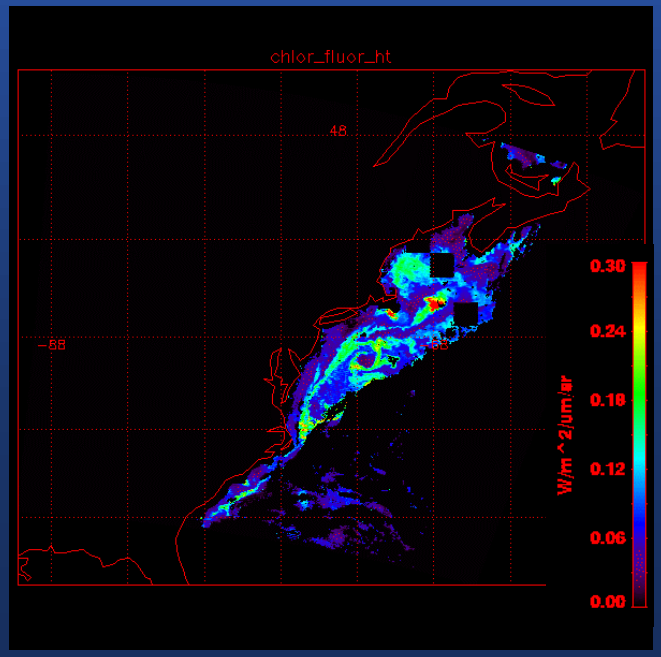
East Coast Image 2001095.1605



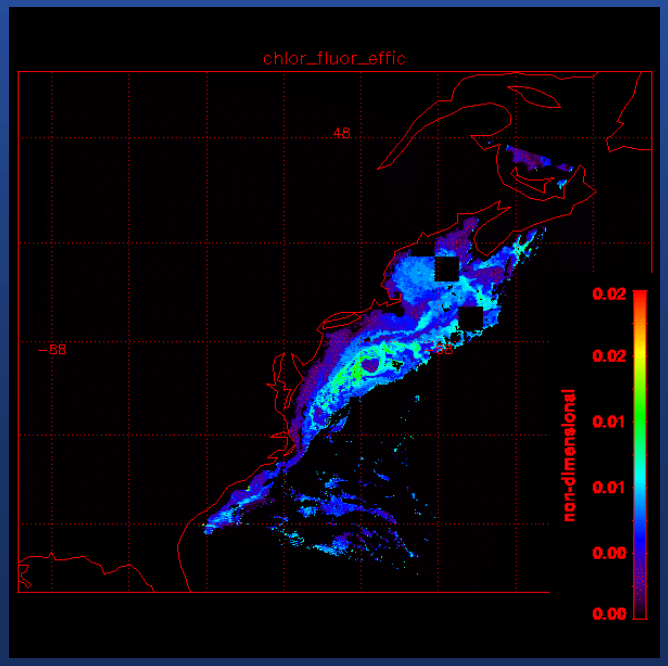
Chl MODIS



ARP

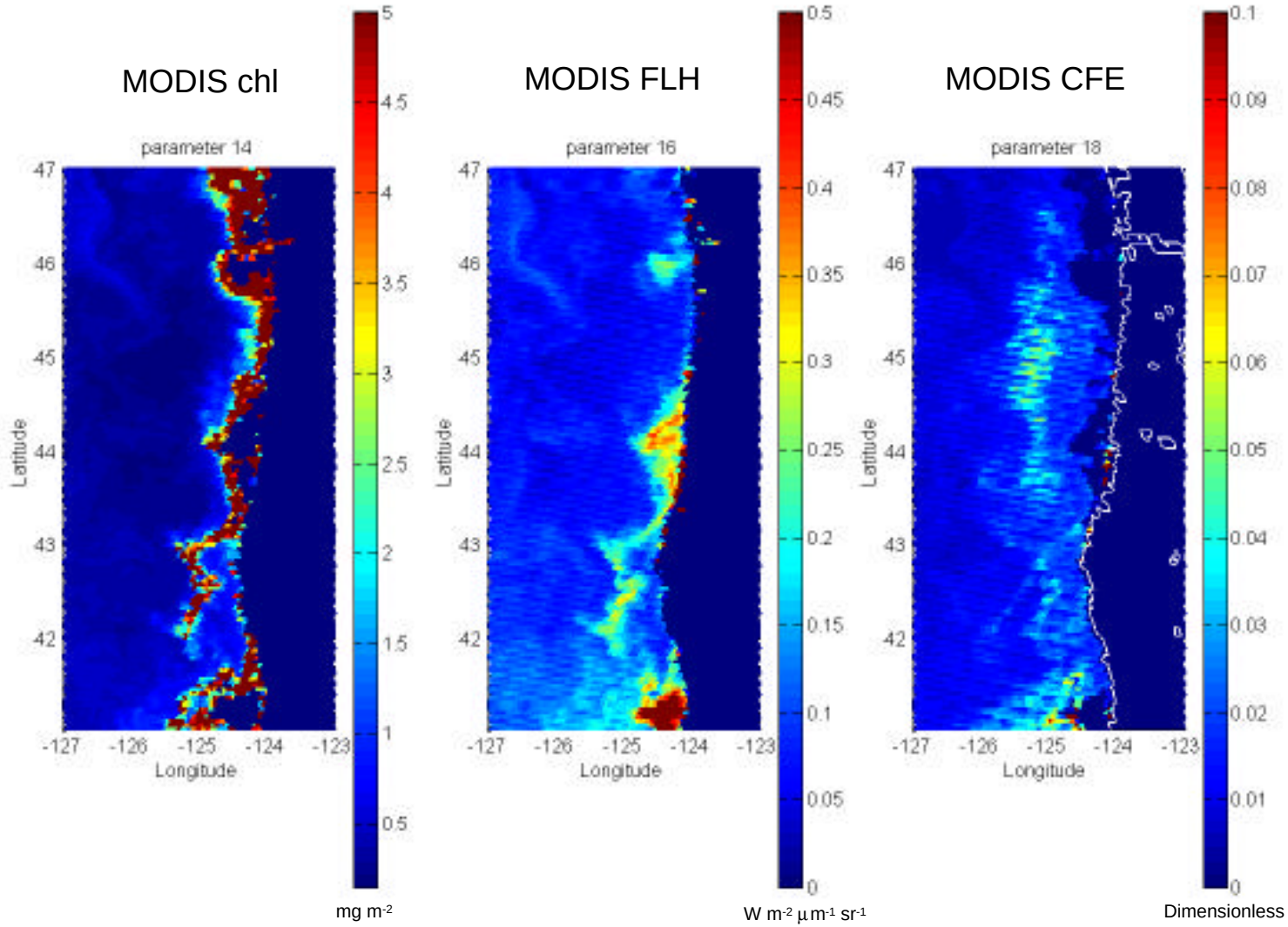


FLH

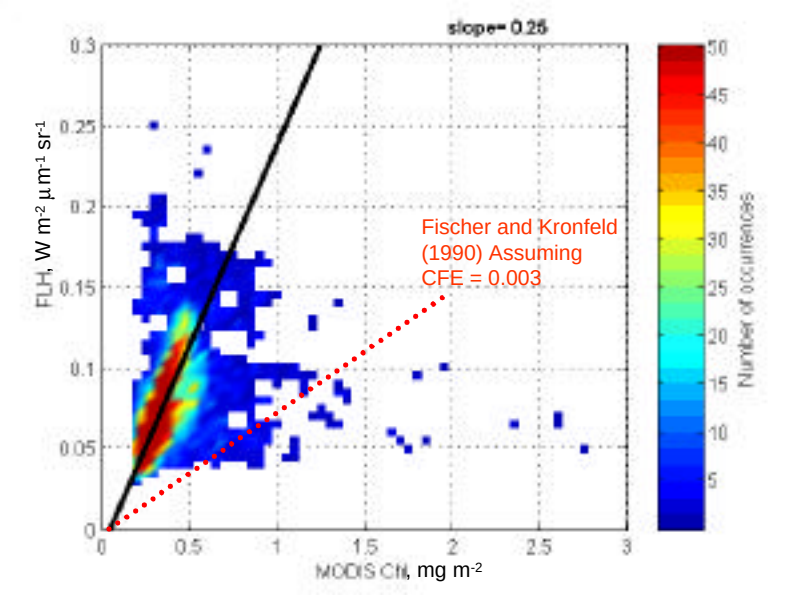


CFE

OSU Direct Broadcast 2001150 Image 4 km Level 3
(NASA Level 0 -> 1b processing code ver. 1.3 & Miami Ocean Code dated 11/30/2001)



Oregon Coast DB Image 2001150



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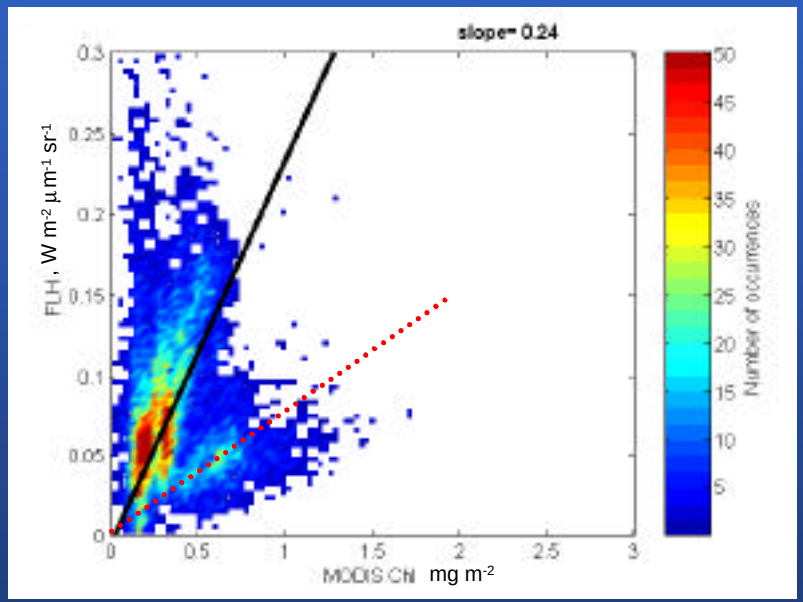

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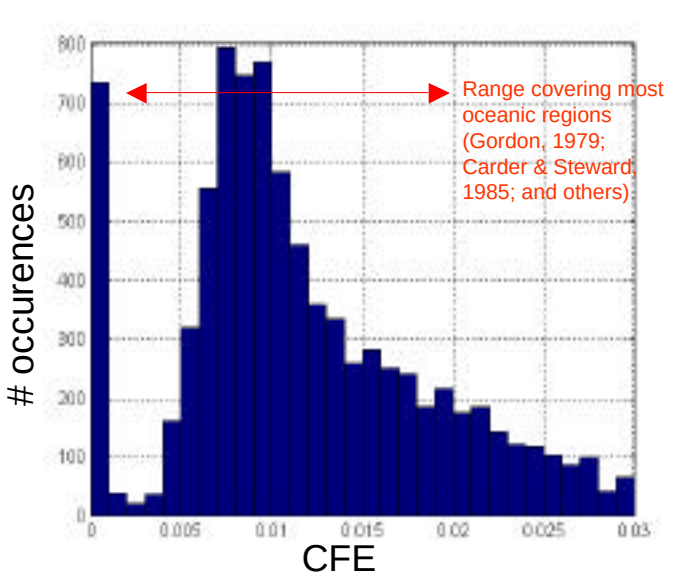

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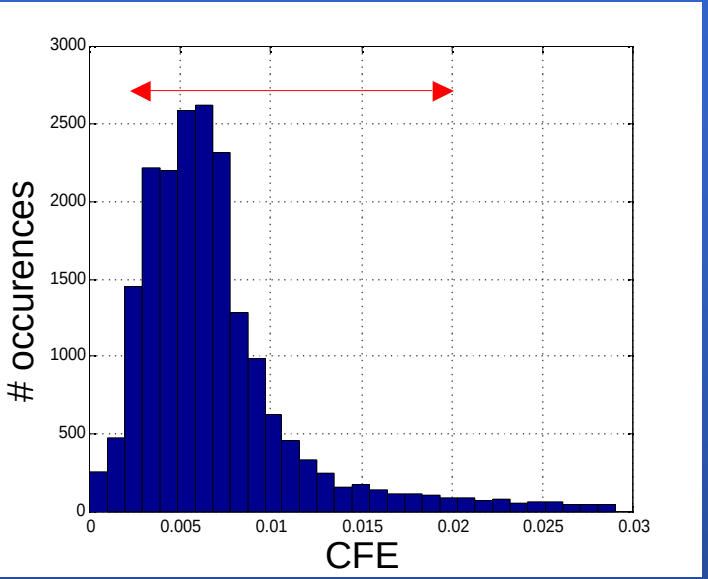

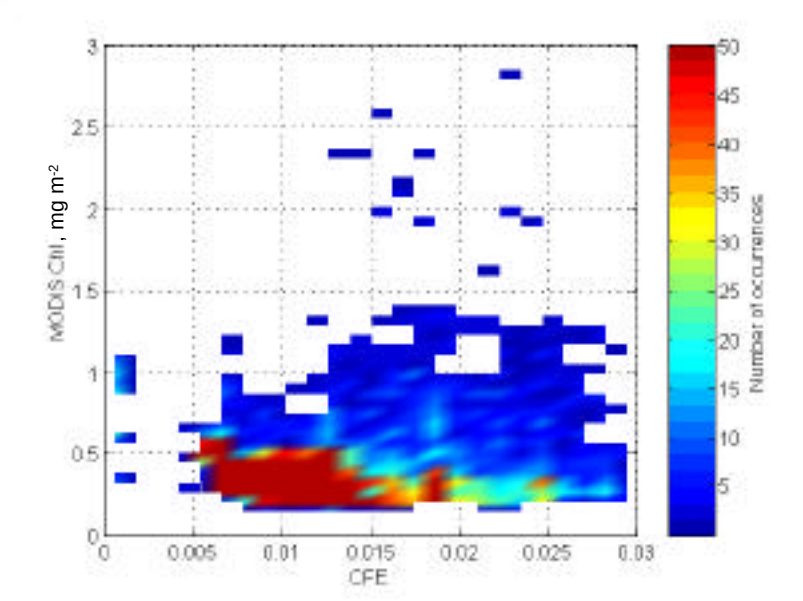

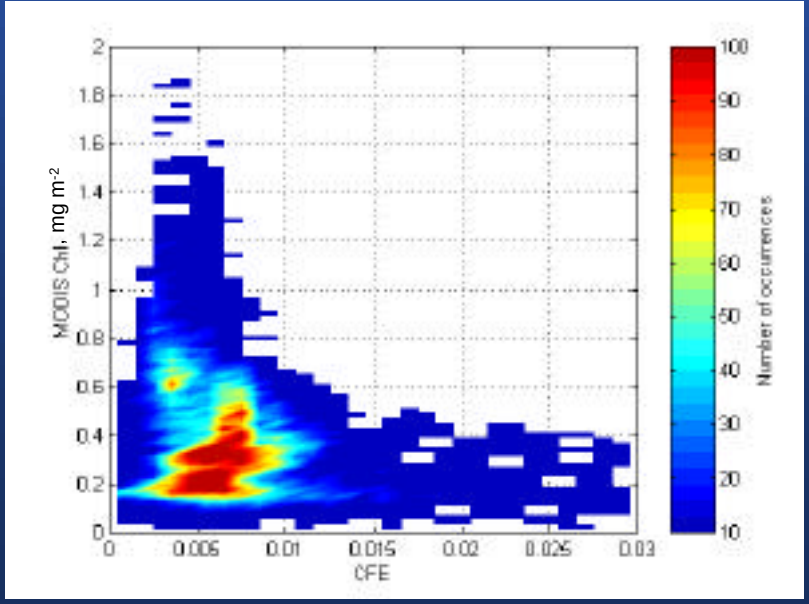

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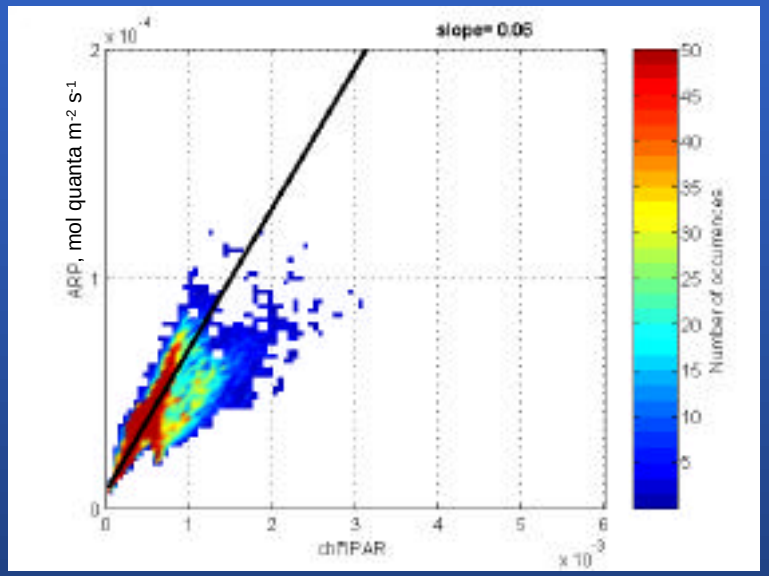
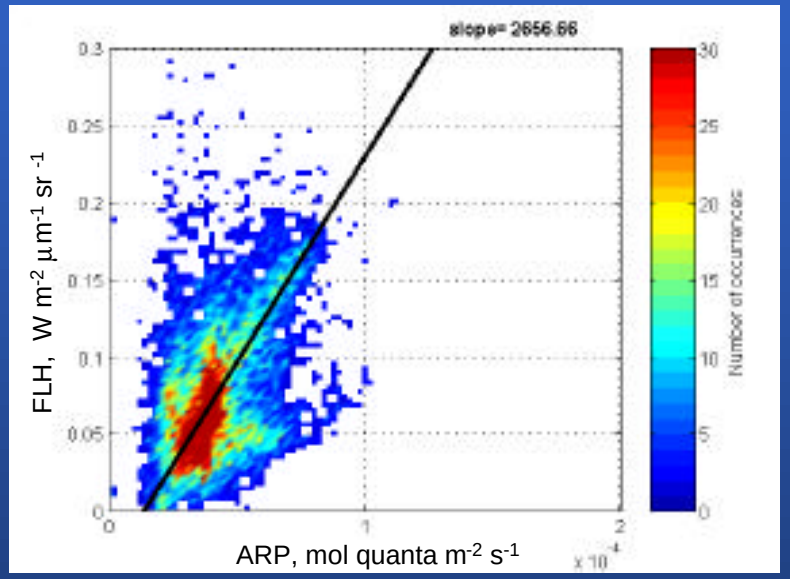
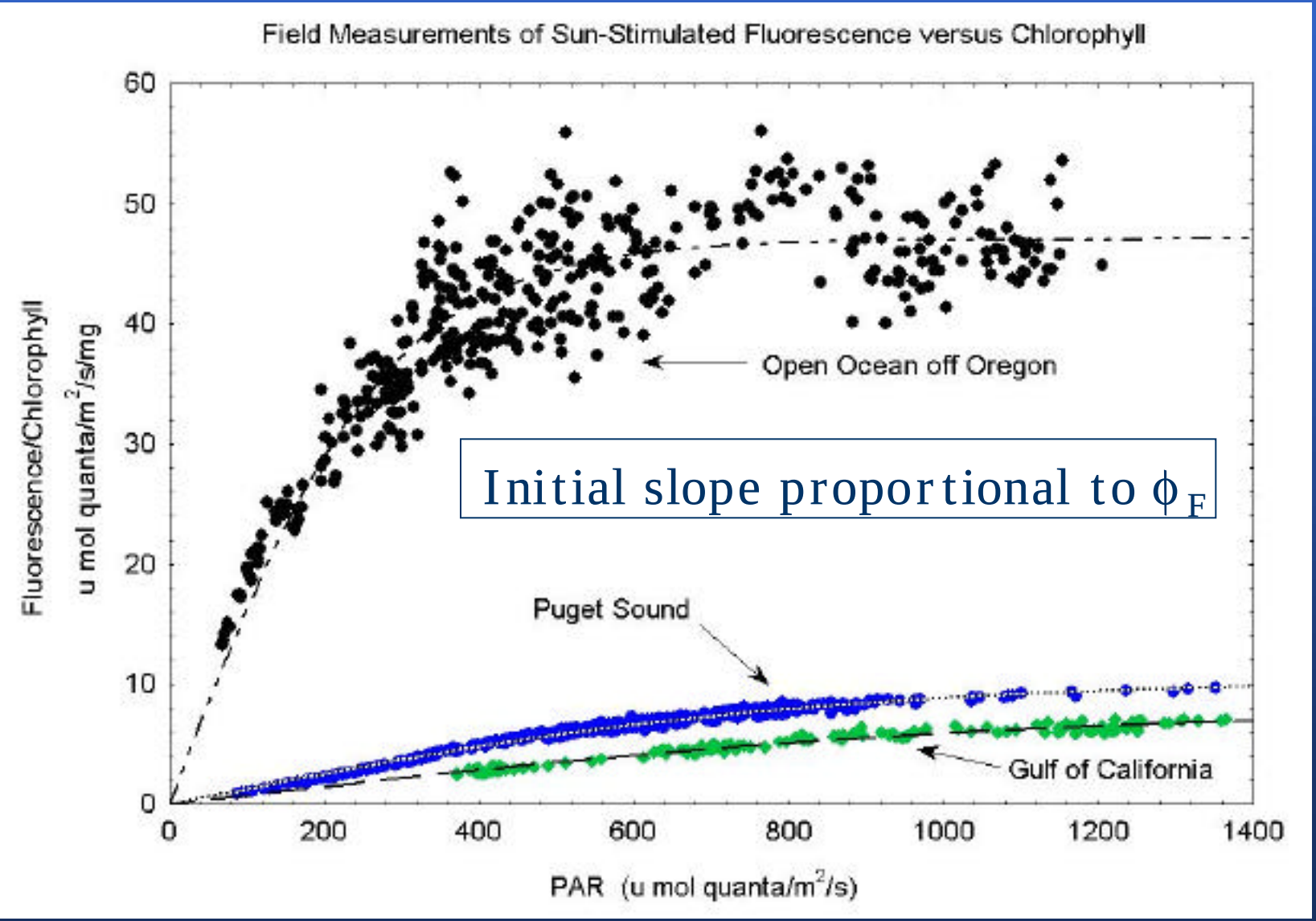


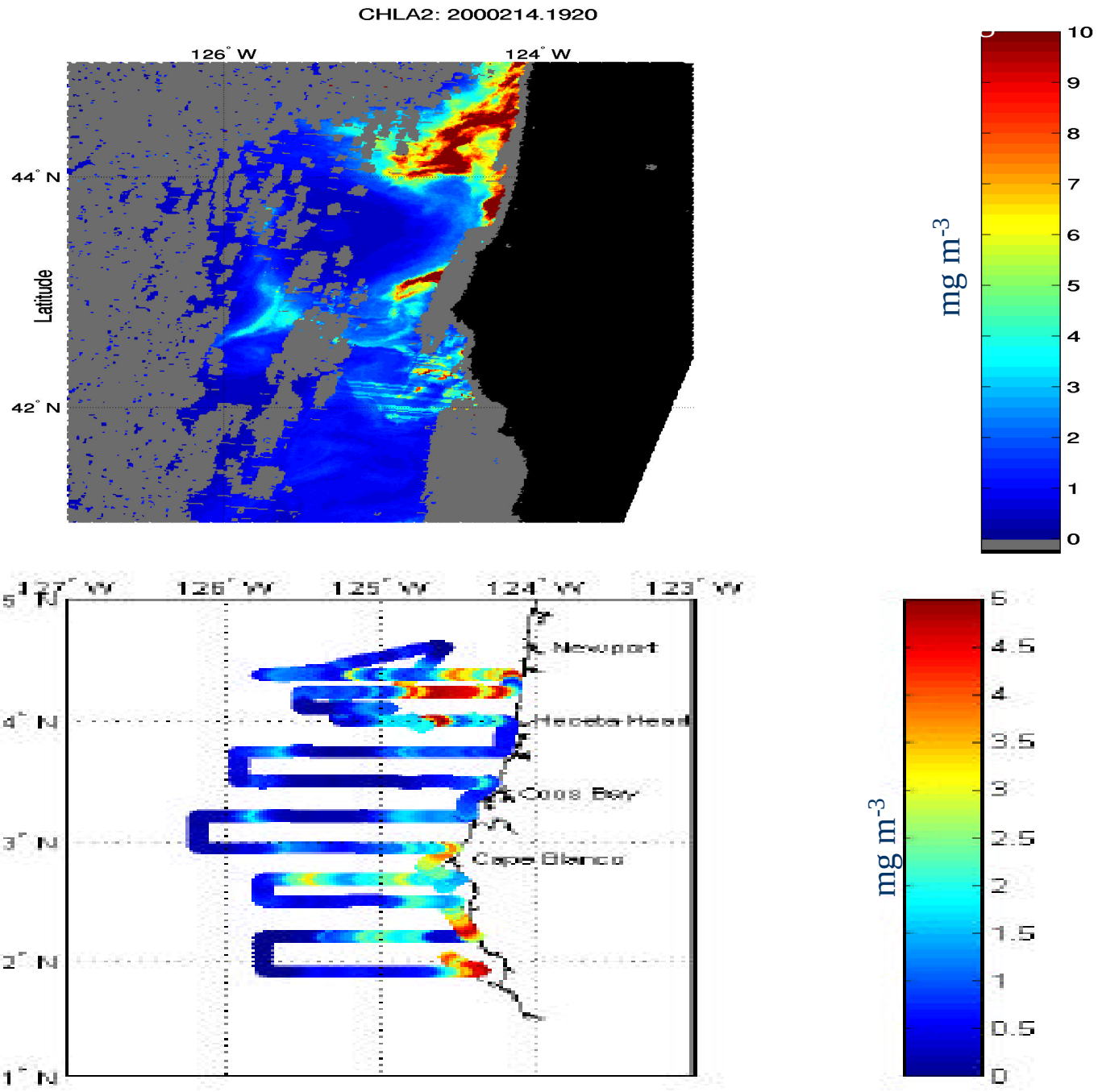
Variability in a*



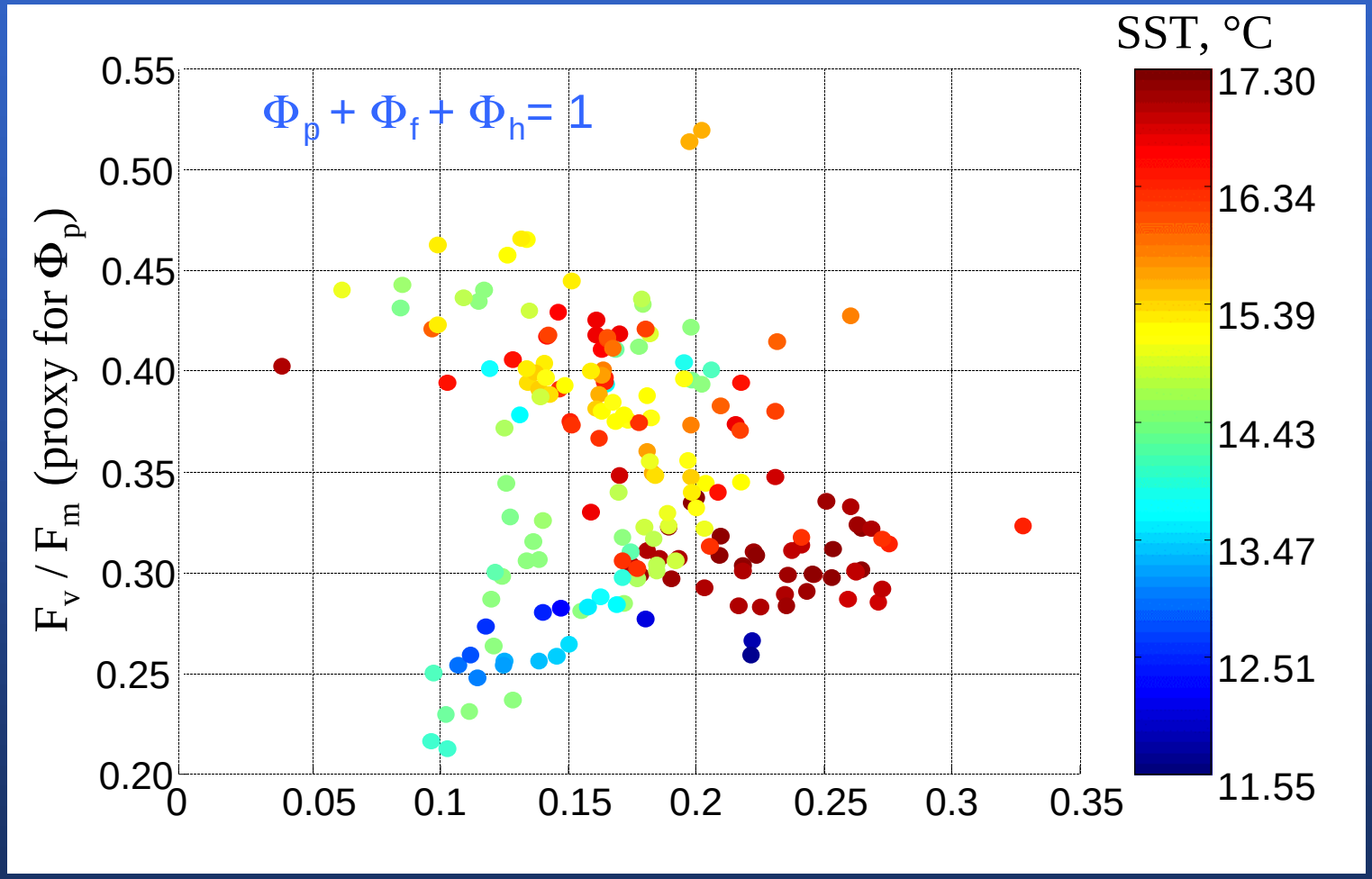
Variability in CFE (or Φ_f)

In Situ Observations of F/[chl]

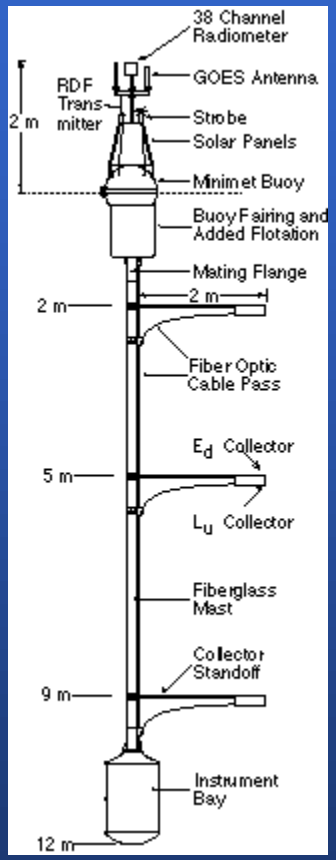



CHLA2: 2000214.1920
126° W
124° W
44° N
42° N
Latitude
mg m-3
0
1
2
3
4
5
6
7
8
9
10
127° W
126° W
125° W
124° W
123° W
45° N
44° N
43° N
42° N
41° N
Newport
Heceta Head
Coos Bay
Cape Blanco
Latitude
Longitude
mg m-3
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

FLH/chl vs. F_v/F_m as Function of SST



Ongoing Field Observations



- In situ open ocean
  - MOBY
  - HOT cruises

- In situ Coastal
  - GLOBEC (2002)
  - COAST (2003)

- Southern Ocean SOFeX

Validation vs. Characterization

- The validity of a product depends on the scientific question (i.e. relative vs. absolute changes).

  The validity can be determined by the user by looking into the characterization of the uncertainties in a given MODIS product.