Remote Sensing and Ocean Iron Fertilization

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What Iron Fertilization Looks Like from Space

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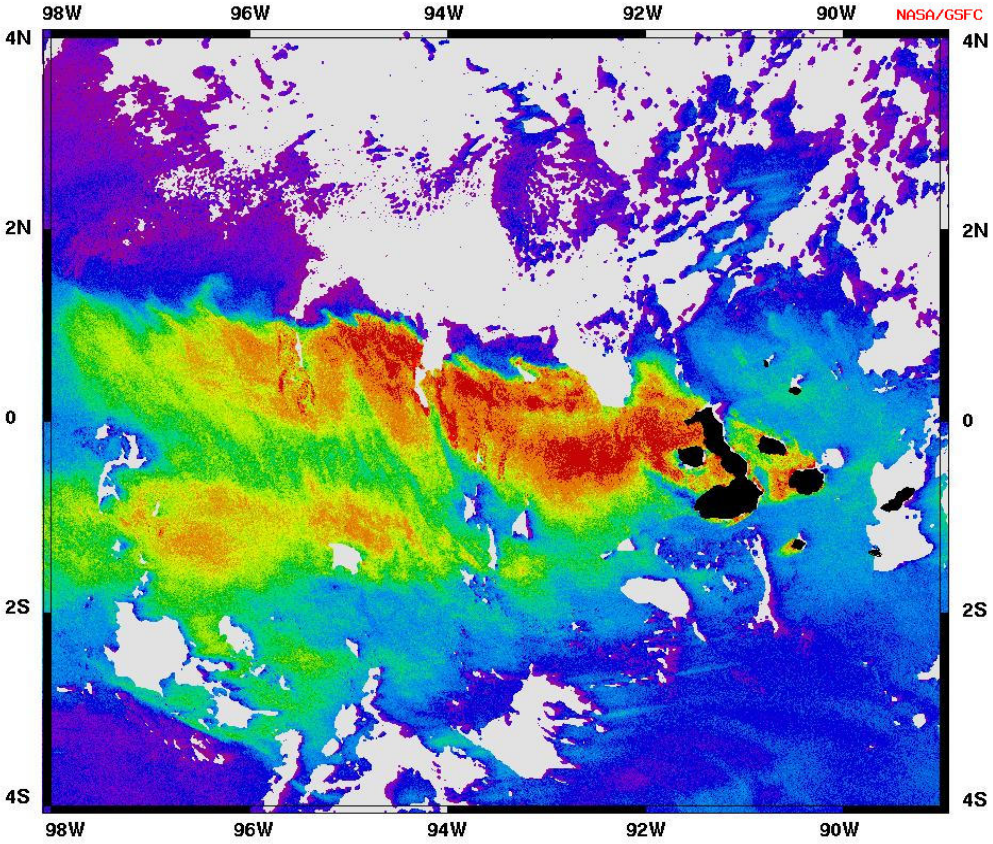
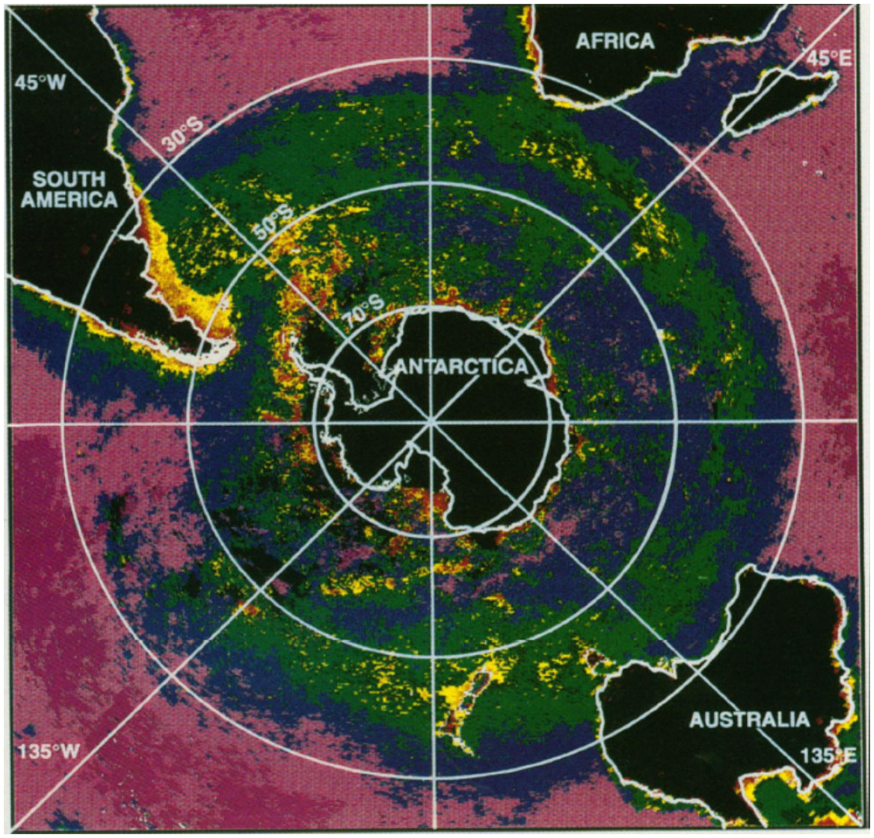
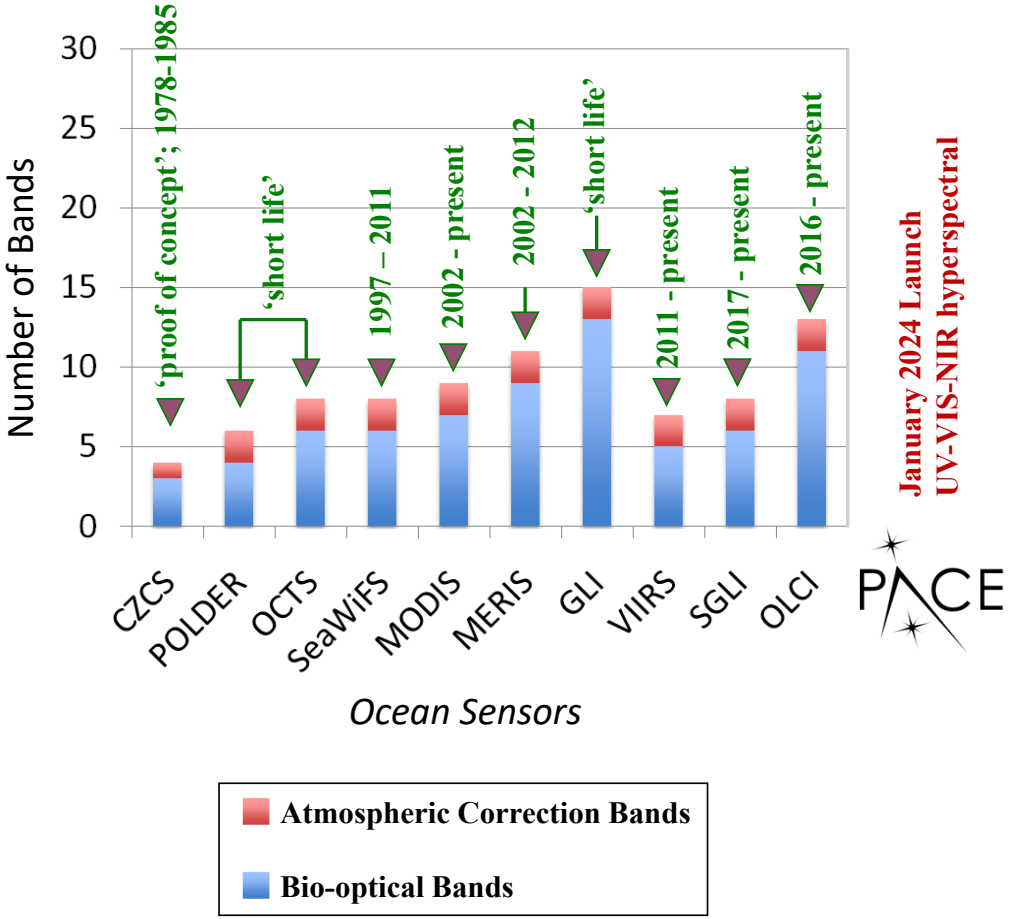
Coastal Zone Color Scanner (CZCS)





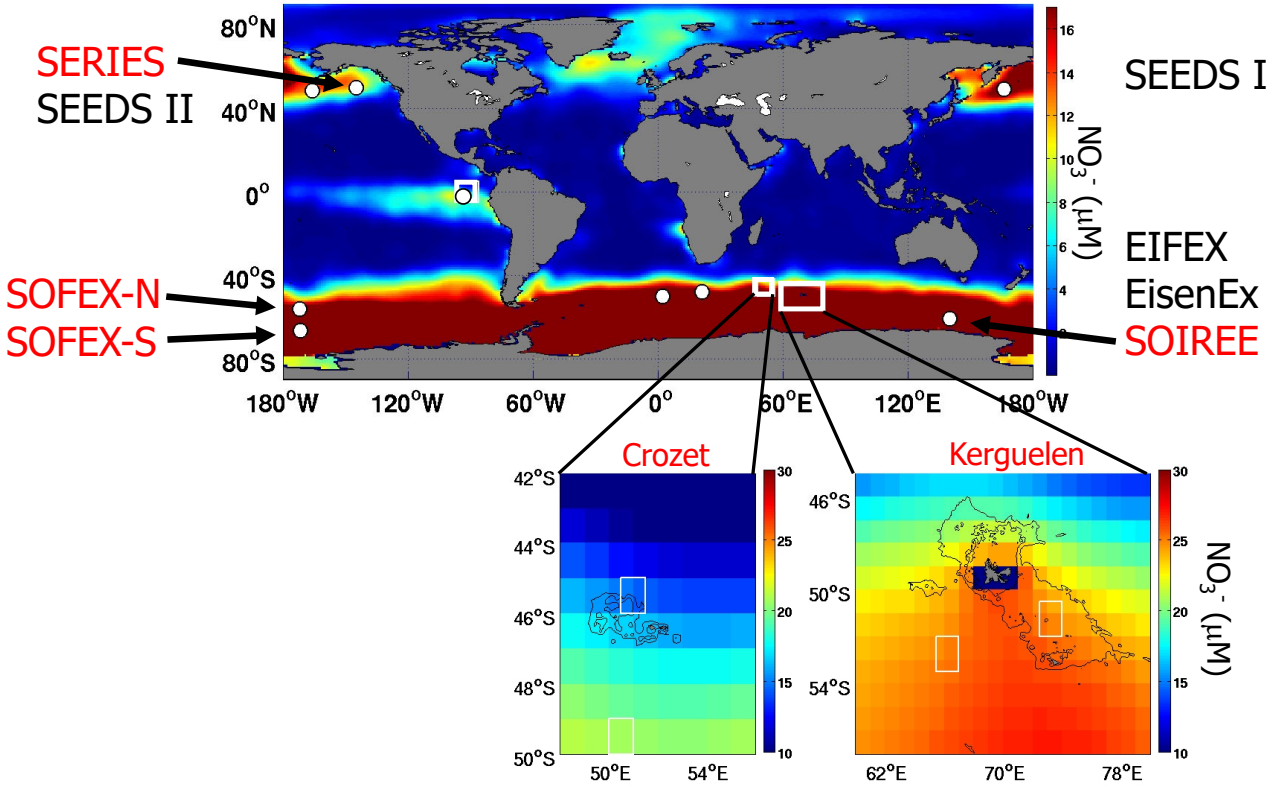
From: Sullivan et al. 1993 Science



Additional Relevant Developments

- Inversion Algorithms
  - Chlorophyll (biomass & physiology)
  - Phytoplankton Carbon (biomass)
  - Chl:C (physiology)

- Chlorophyll Fluorescence



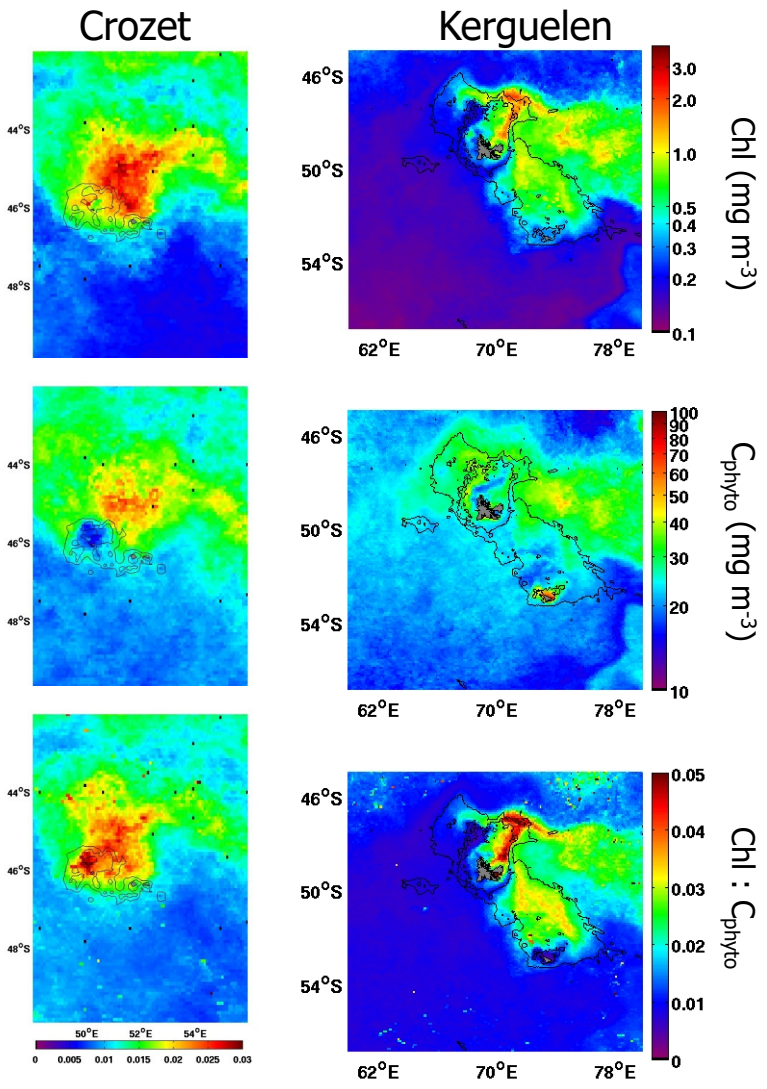
From: Westberry et al. (2013) *Deep Sea Research I* 73:1-16

Natural OIF

- Strong and broad enhancement of chlorophyll downstream of island, with stark contrast to upstream waters

- Response of C_{phyto} is clear, but not as broad or intense as chlorophyll and with smaller difference between upstream and downstream waters

- Chl:C_{phyto} ratio indicates broadly enhanced division rates in Fe-enriched water, but concurrent influence on biomass also depends on ability of grazing and other losses to respond

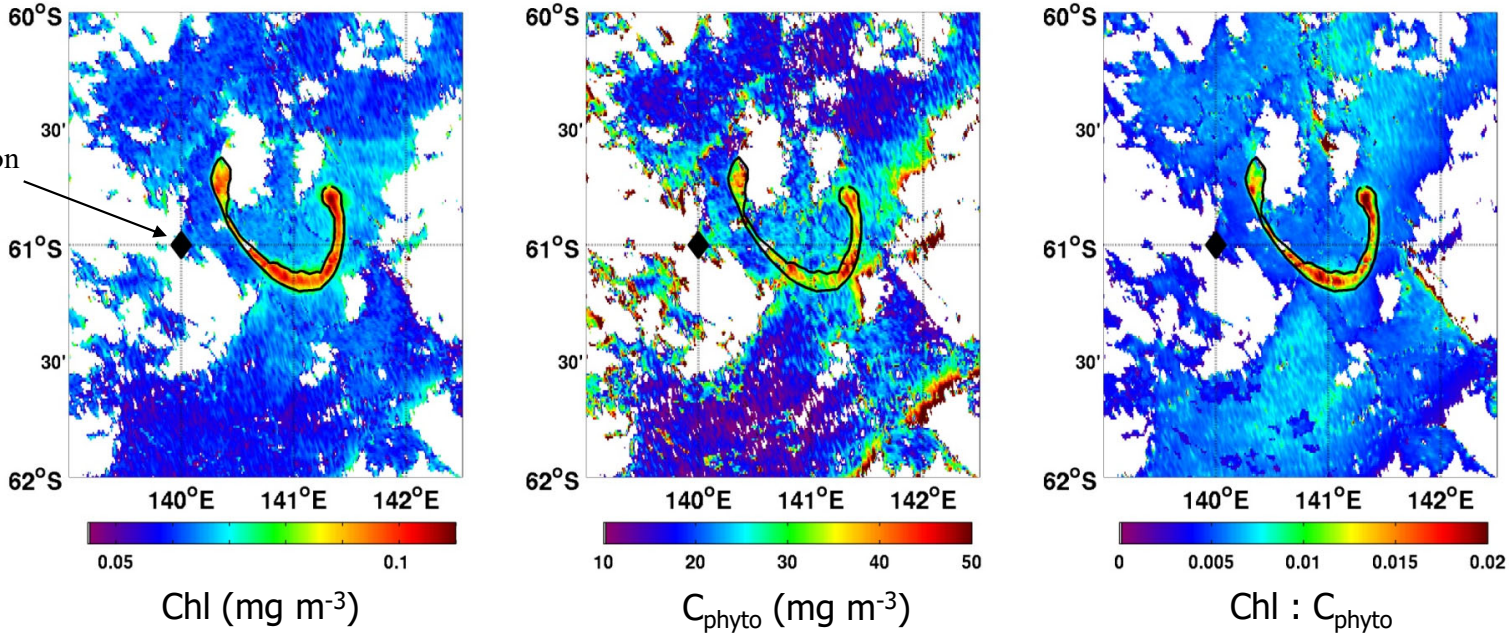


From: Westberry et al. (2013)

Mesoscale OIF – SOIREE (Southern Ocean Iron RElease Experiment)

- 1st "satellite-era" OIF (Feb. 1999)
- Image from ~ 45 days after fertilization

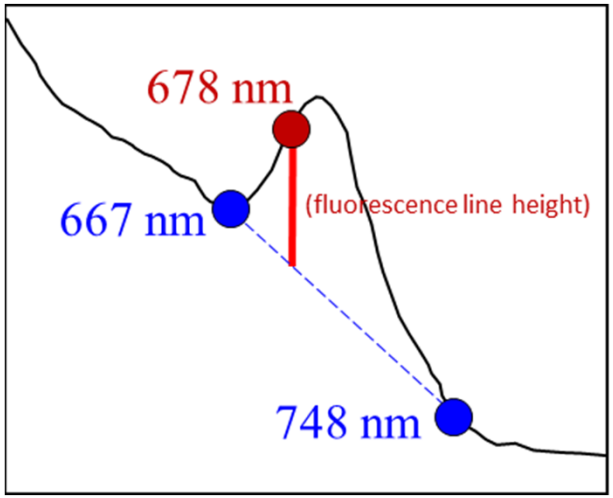
geographic location of iron addition



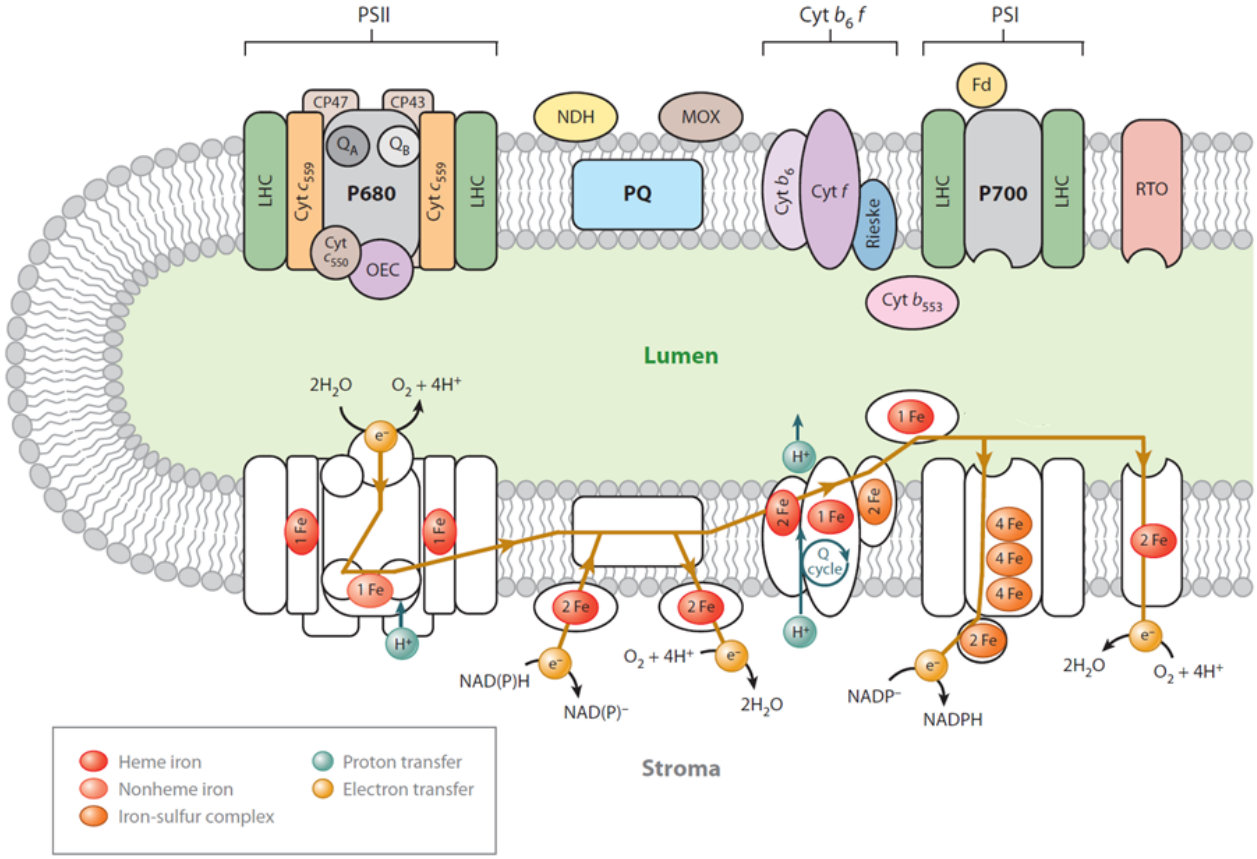
From: Westberry et al. (2013)

Chlorophyll Fluorescence

- MODIS Aqua (2002)
- MERIS
- OLCI



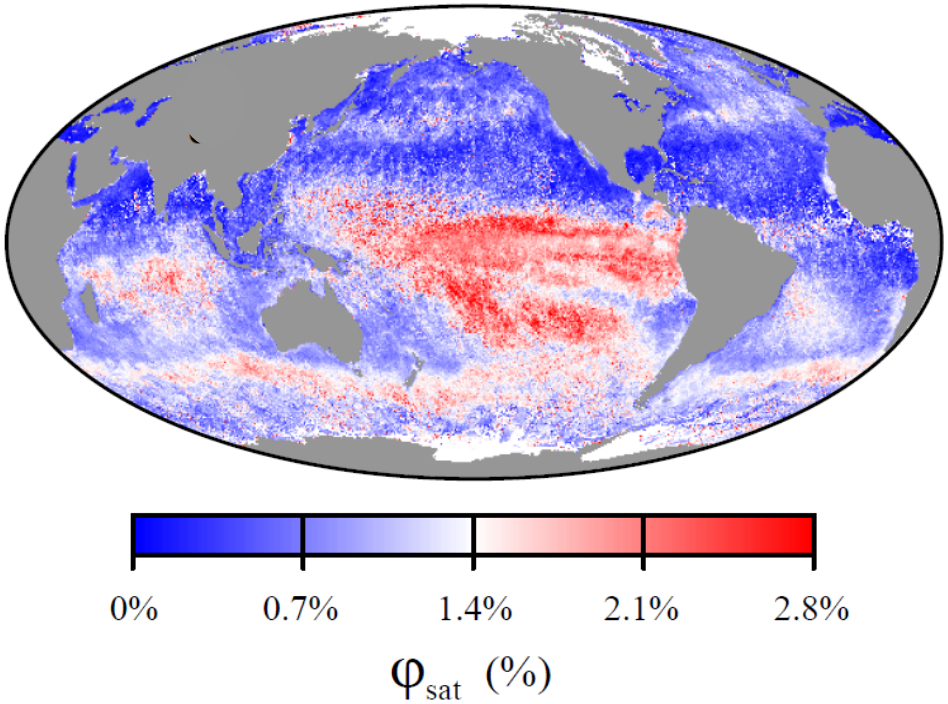
Fe in photosynthetic electron transport



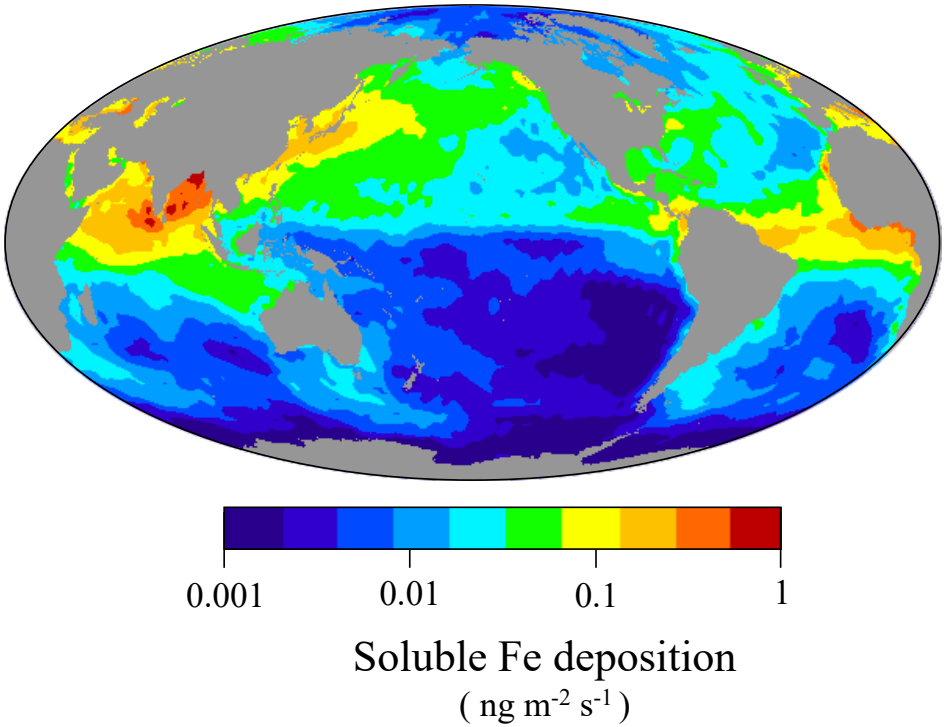
From: Behrenfeld & Milligan (2012)

Chlorophyll Fluorescence

satellite

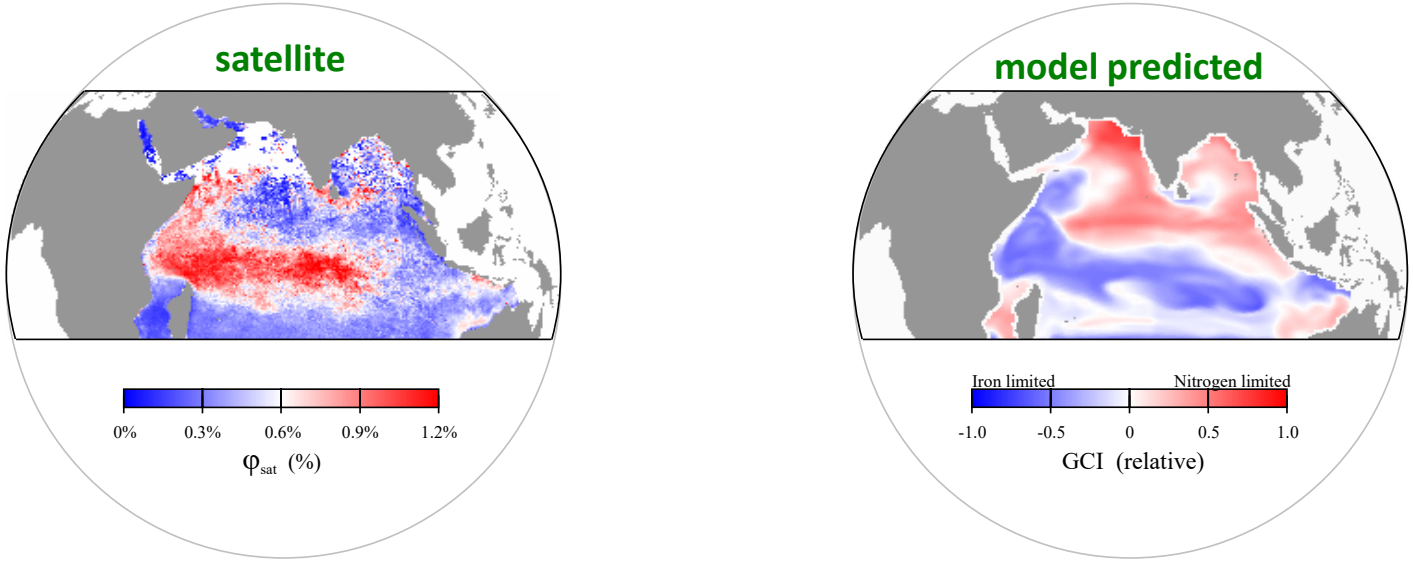


model prediction



From: Behrenfeld et al. (2009)

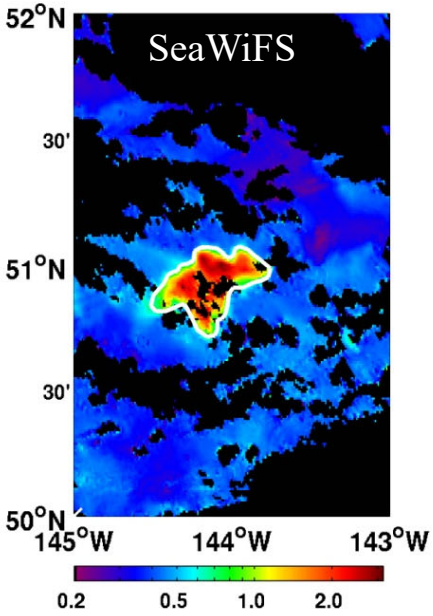
Chlorophyll Fluorescence



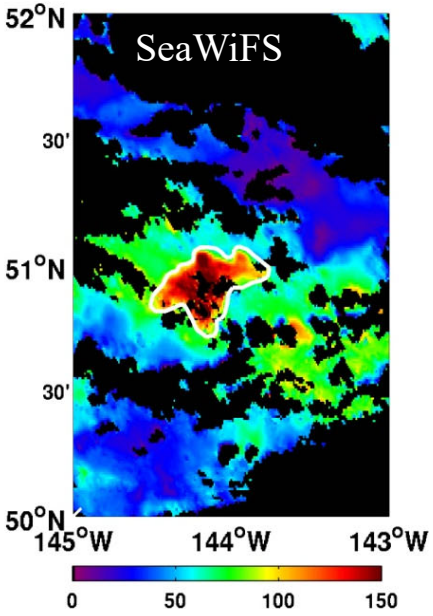
From: Behrenfeld et al. (2009)

Mesoscale OIF – SERIES (Subarctic Ecosystem Response to Iron Enrichment Study)

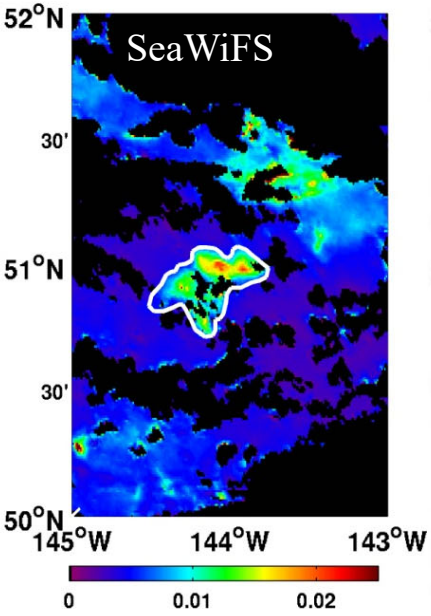
- July 2002
- Subarctic northeast Pacific
- Image from ~20 days after fertilization



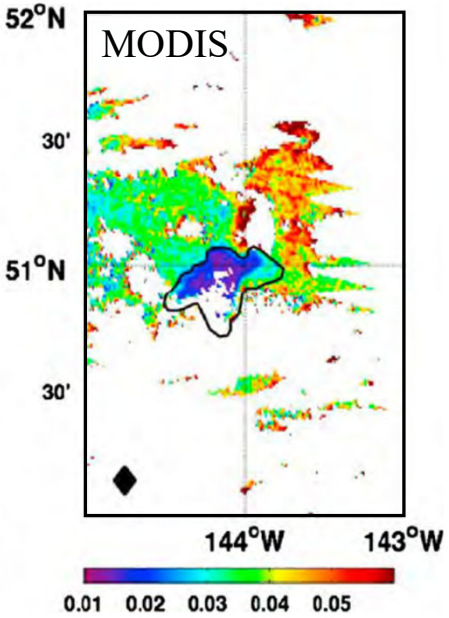
Chl (mg m^{-3})



C_{phyto} (mg m^{-3})



Chl : C_{phyto}



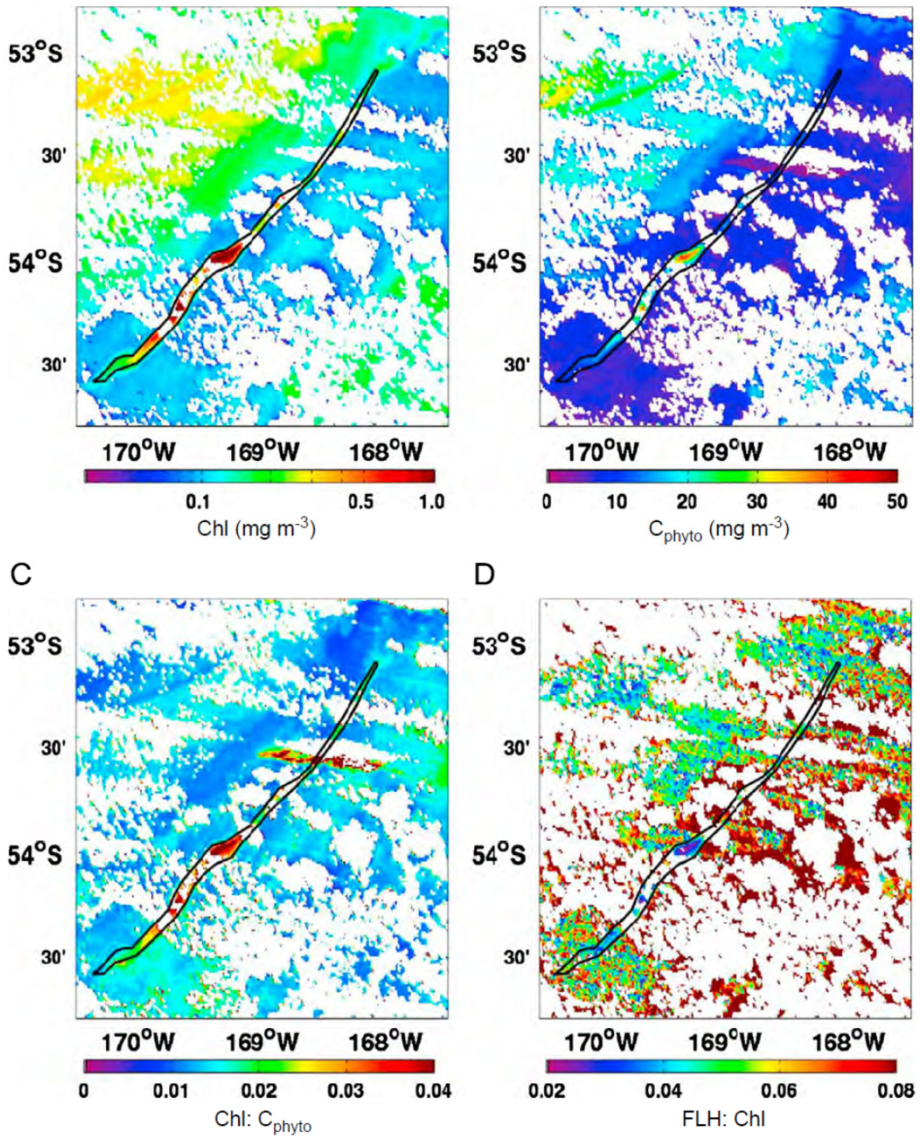
FLH:Chl

From: Westberry et al. (2013)

Mesoscale OIF – SOFEX-N

(Southern Ocean Iron Experiment - North)

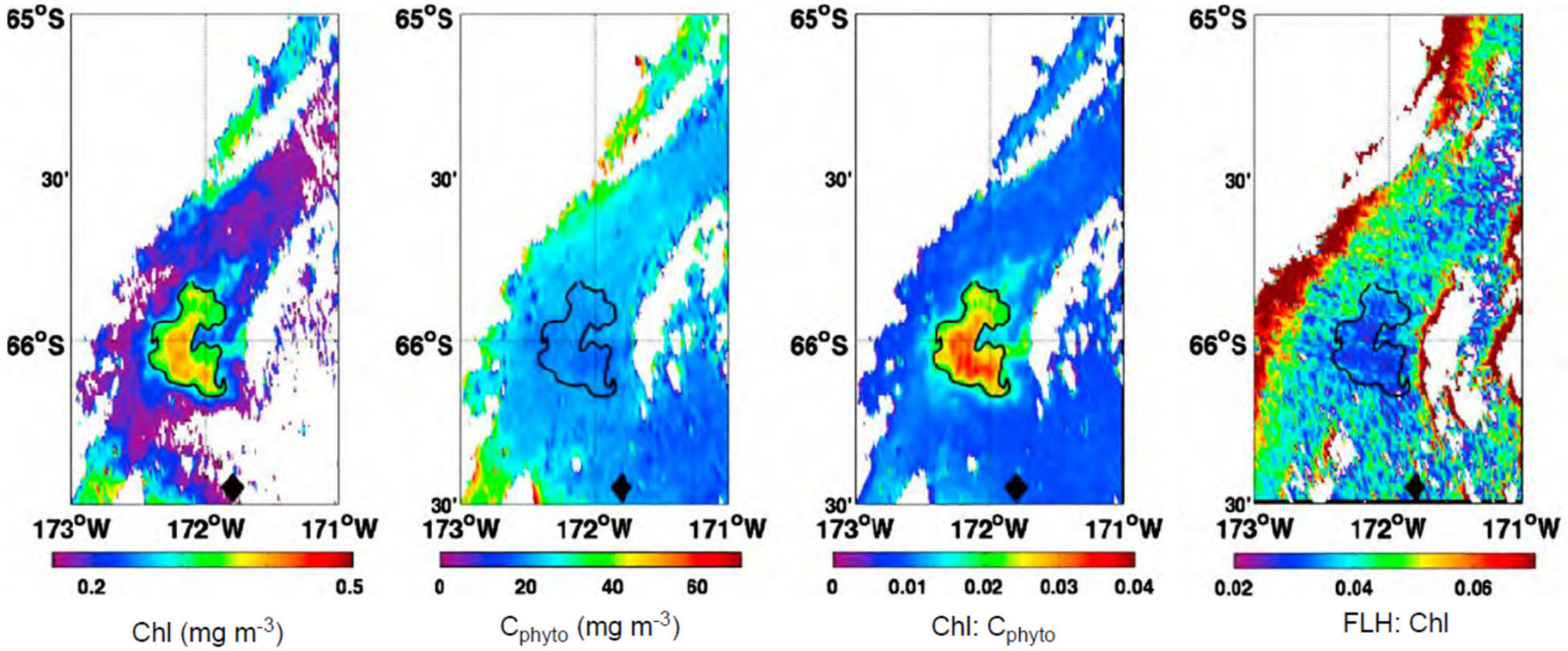
- February 2002
- Southern Ocean
- Image from 26 days after fertilization



From: Westberry et al. (2013)

Mesoscale OIF – SOFEX-S (Southern Ocean Iron Experiment - South)

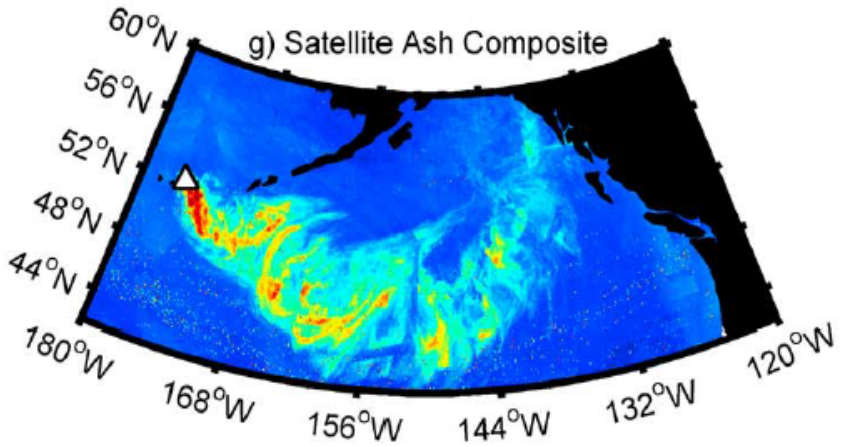
- February 2002
- Southern Ocean
- Image from 19 days after fertilization

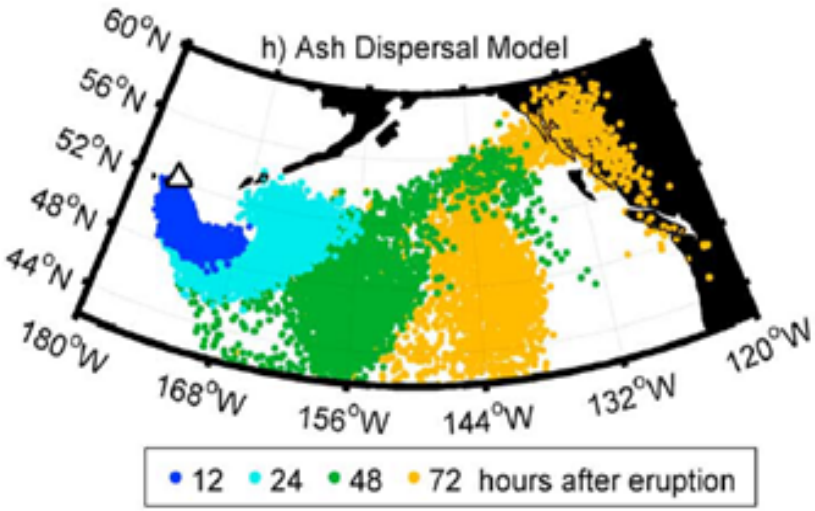


From: Westberry et al. (2013)

Natural OIF from Above

- February 2002
- Mt Okmok & Kasatoschi eruptions

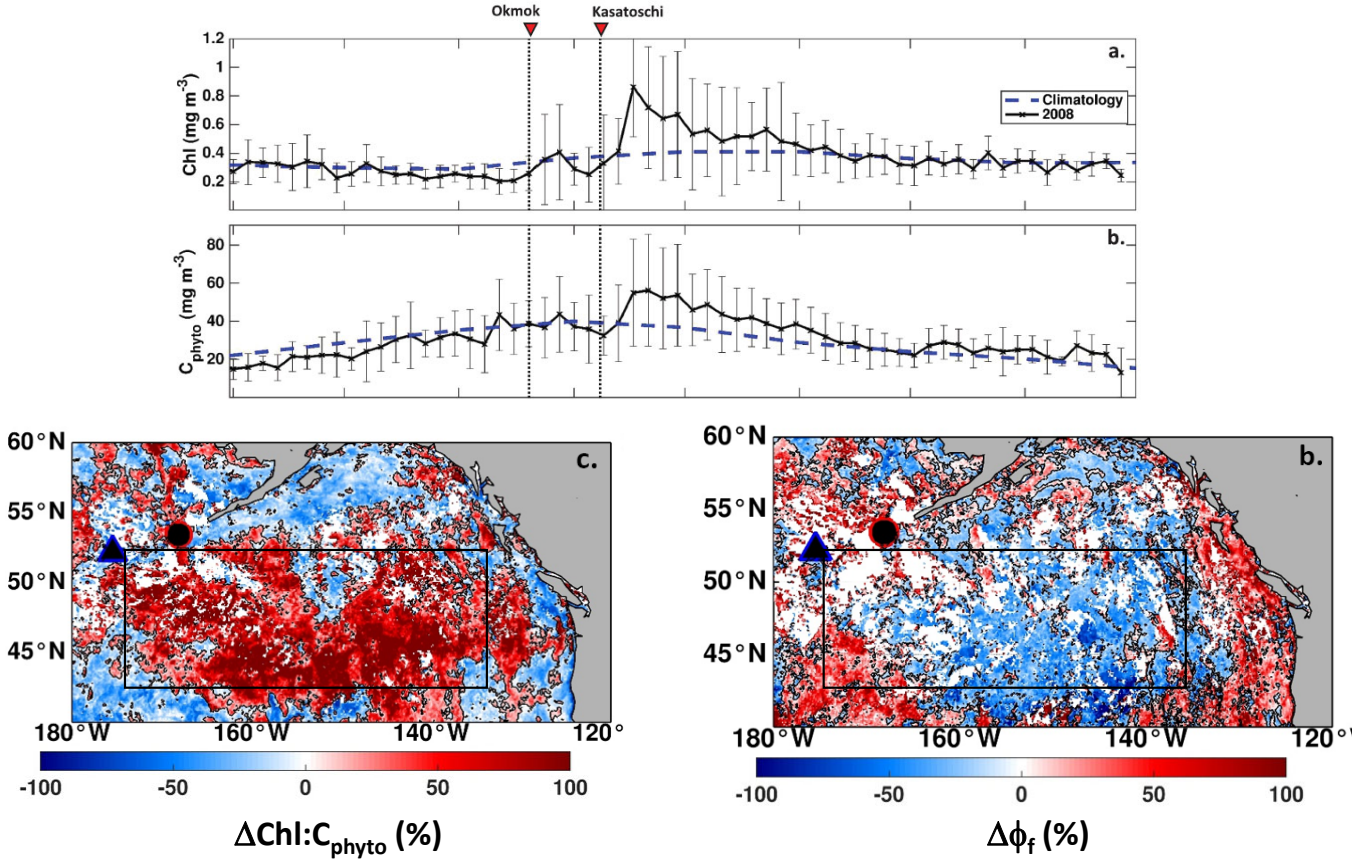




From: Hamme et al. (2010)

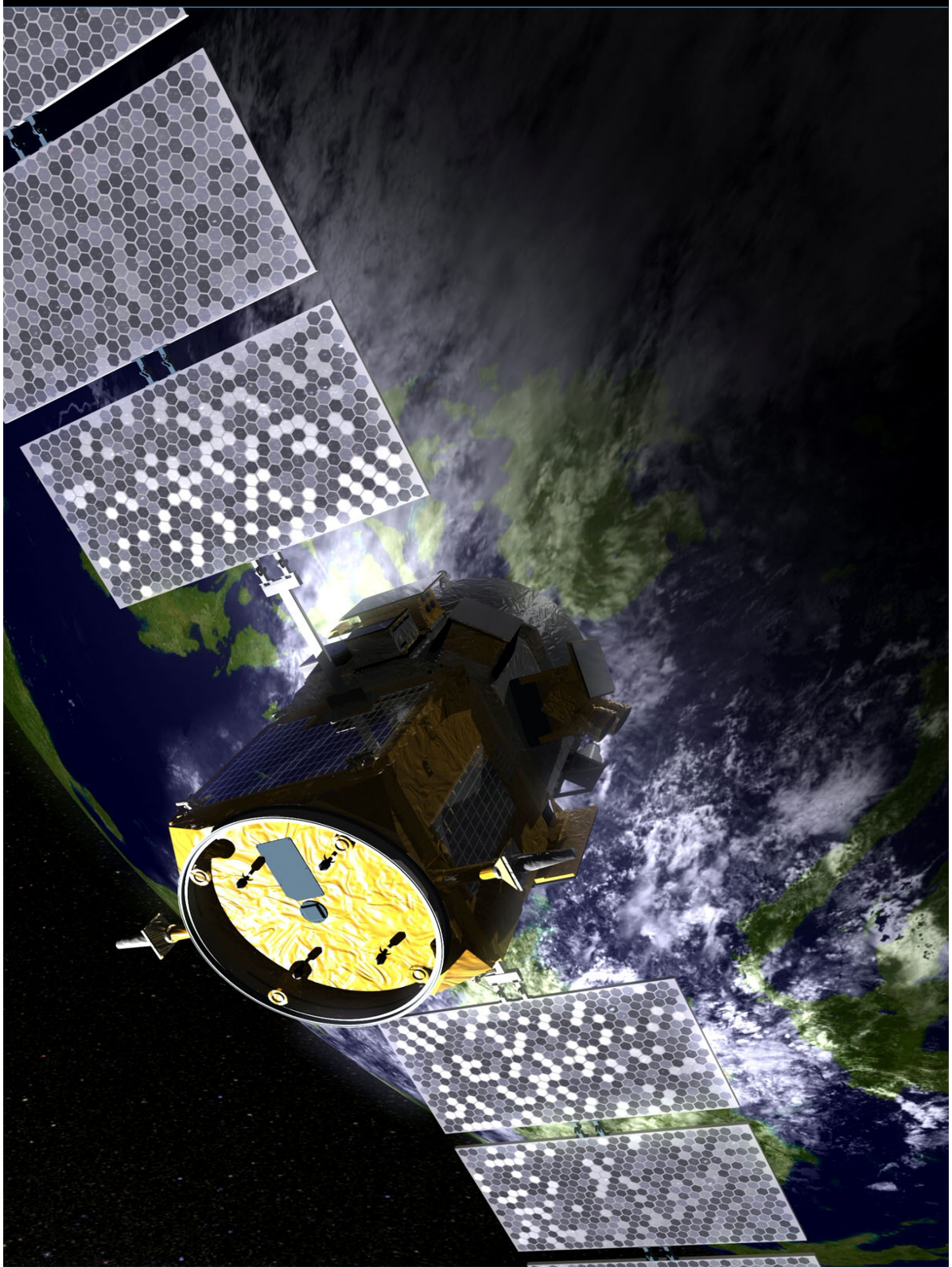
Natural OIF from Above

- February 2002
- Mt Okmok & Kasatoschi eruptions



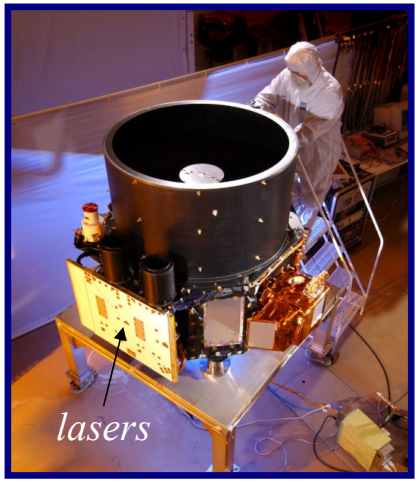
From: Westberry et al. (2019)

Satellite Lidar in Oceanographic Research

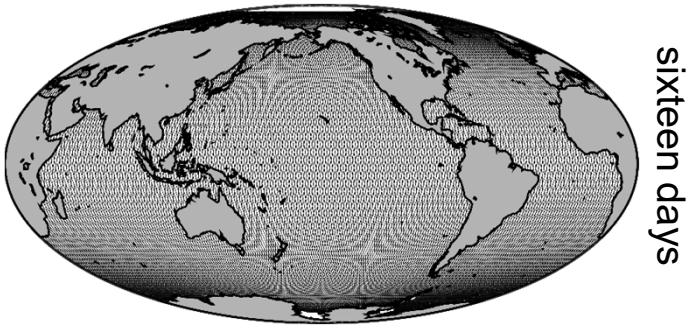


Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP)

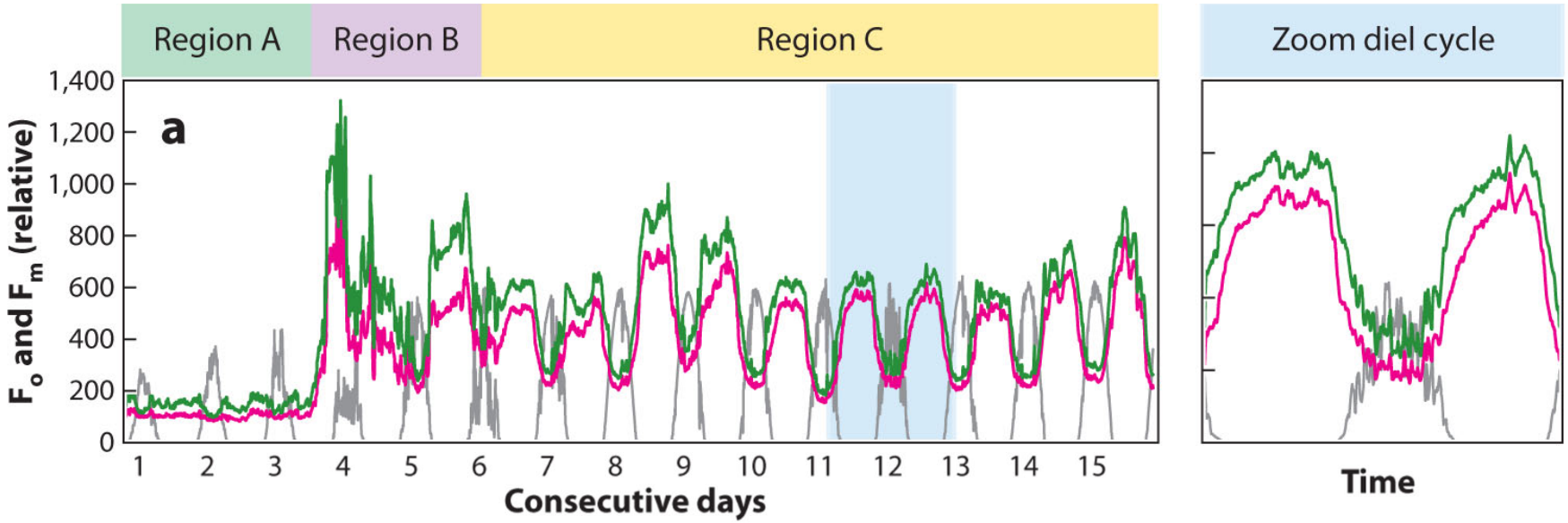
- NASA-CNES partnership
- 2006 – summer 2023
- 2-wavelength 110 mJ Nd:Yg laser (532, 1064 nm)
- 3-channel (532∥, 532 ⊥ , 1064 nm)
- 23 m water vertical resolution



- 'Proof of Concept'
- Global assessments of C_{phyto}, POC
- Complete annual polar plankton cycles
- Diel vertical animal migration
- Ocean color intercomparisons



Looking Forward…



Agenzia Spaziale Italiana

Cloud Aerosol Lidar for Global Scale Observations of the Ocean-Land-Atmosphere System (CALIGOLA)

(Launch Target 2029)

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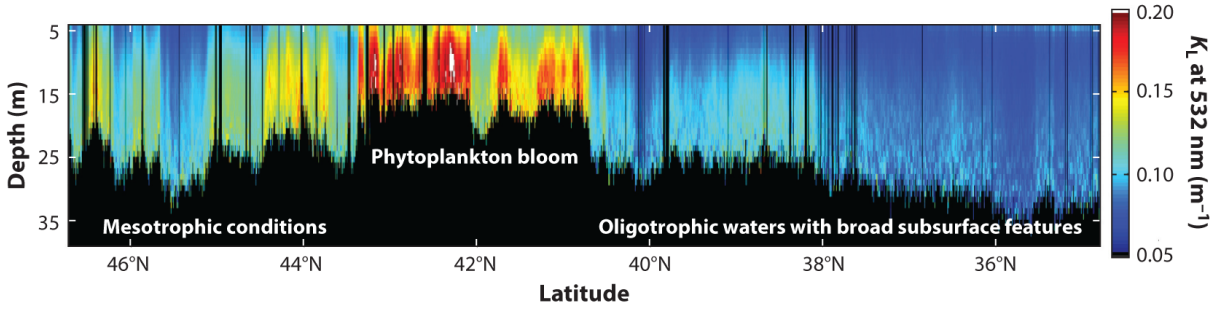
T1. 532 nm co-polarized return
T2. 355 nm co-polarized return
T3. 532 nm cross-polarized return
T4. 300 nm water Raman emission
T5. 405 nm water Raman emission
T6. 1064 nm co-polarized return
B1. 355 nm cross-polarized return
B2. 680 nm chlorophyll fluorescence
V1. 450 nm water Raman emission
V2. 1064 nm cross-polarized return
V3. 466 nm cDOM emission
V4. 532 nm co-polarized and cross-polarized return with enhanced detector dynamic range



Thank you