Interactions between regional climate forming factors and phytoplankton communities in the north-western Pacific

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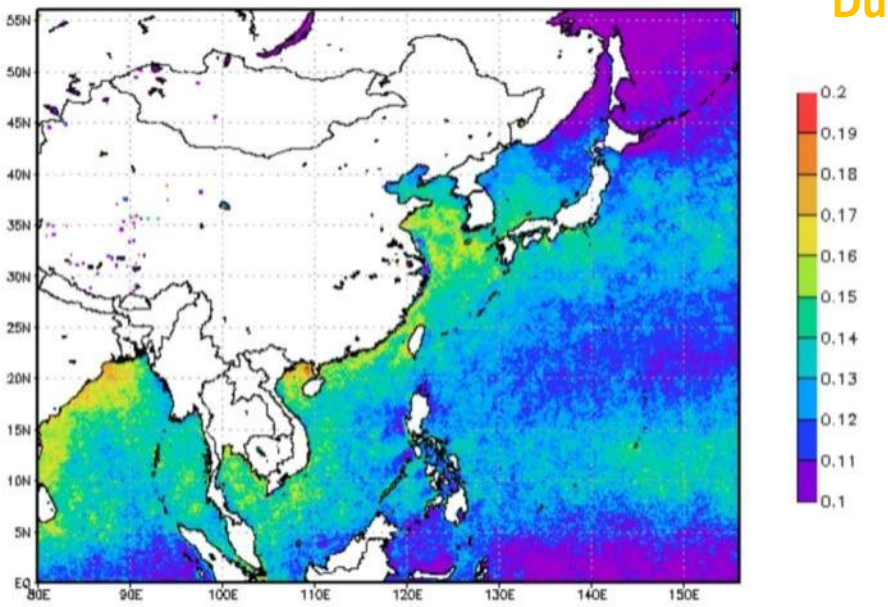
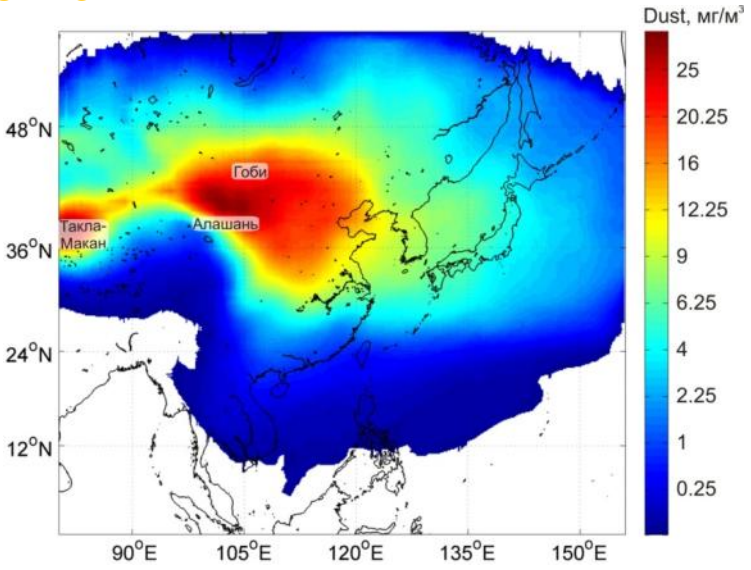
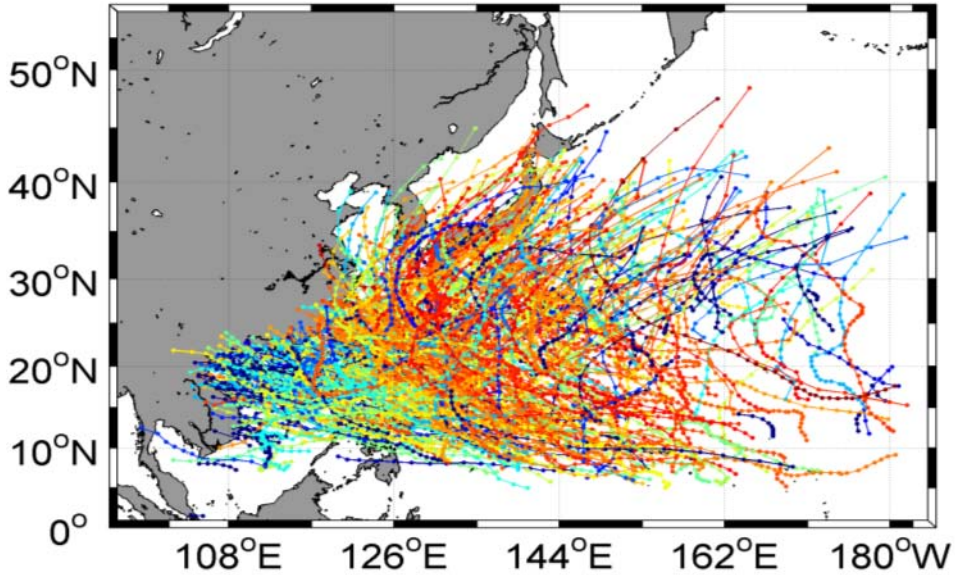
CLIMATE FORMING FACTORS SPECIFIC TO NORTH-WESTERN PACIFIC

Dust storms

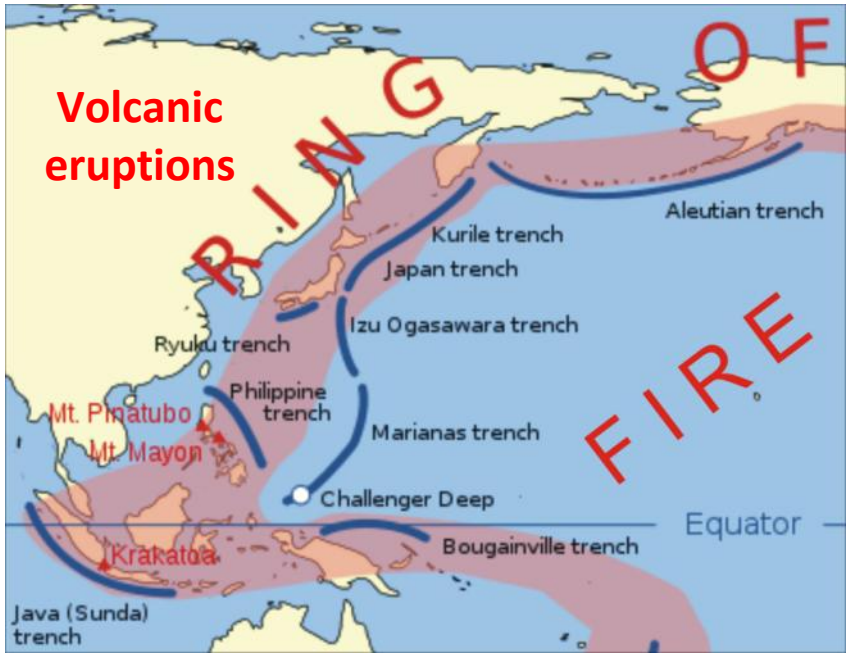




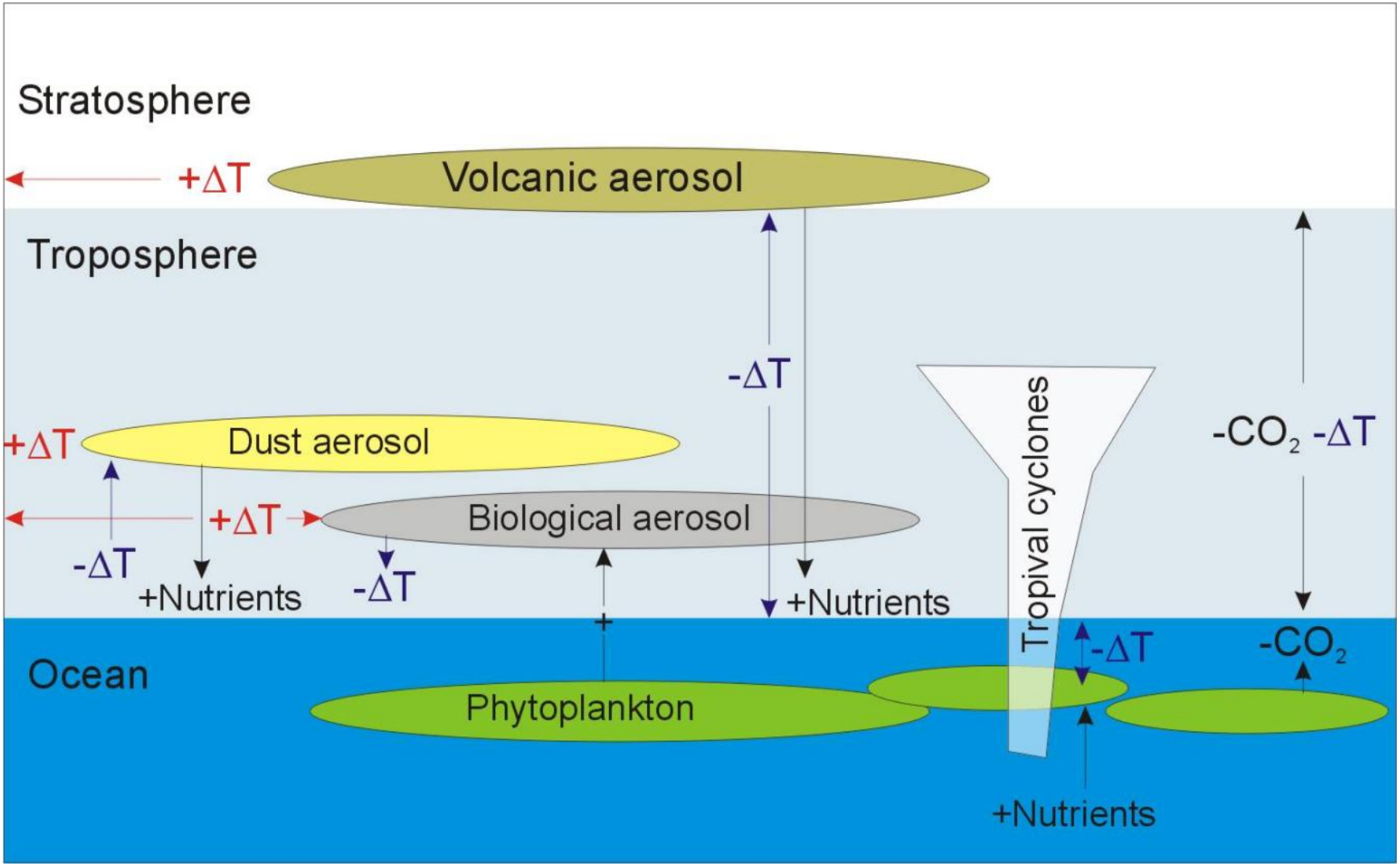
Tropical cyclones



Volcanic eruptions



CONSIDERED CLIMATE FORMING FACTORS INTERACTIONS



USED DATA

Level 03 ocean color data (9x9 km 1-day data)

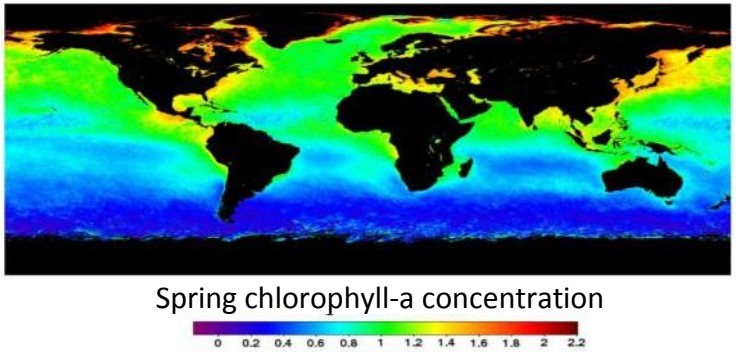
(Ocean Color Web http://oceancolor.gsfc.nasa.gov)

CZCS (1979-1986)
Chlorophyll-a

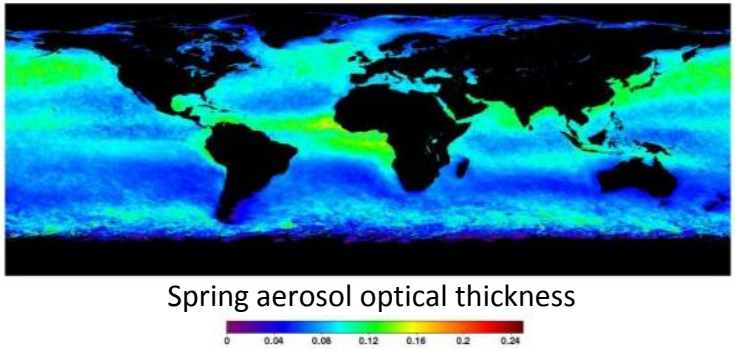
OCTS (1996-1997)
Chlorophyll-a
Aerosol-optical-depth
Angstrom coefficient

SeaWiFS (1997-2010)
Chlorophyll-a
Aerosol-optical-depth
Angstrom-coefficient

MODIS-Aqua (2002-Present)
Chlorophyll-a
Aerosol optical depth
Angstrom coefficient
Sea-surface temperature



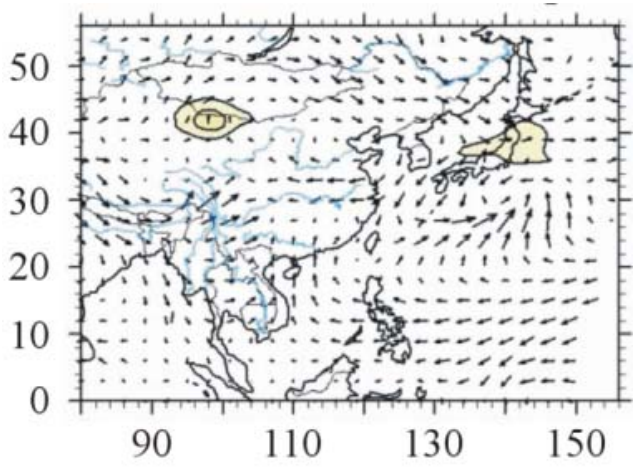
Spring chlorophyll-a concentration



Spring aerosol optical thickness

Tropical cyclones track

Japan Meteorological Agency
http://www.jma.go.jp/jma/indexe.html
Tropical cyclones tracks from 1951 to 2010



Asian Dust concentration (~17x17 km 1-day data)

Chemical weather FORecast System
http://www.jma.go.jp/jma/indexe.html
2003-Pesent data set

PROBLEMS OF USING ONLY SATELLITE DATA

1. Identify type of aerosol

It is hard to separate clouds, water aerosol, dust and volcanic aerosol

Possible solutions: Use only clear cases when several criteria point at considered atmosphere event

2. Errors in atmosphere correction

Presence of dust or volcanic aerosol can lead to false chlorophyll-a concentration increasing observed from satellite

Aerosol increase -> Registered signal from satellite decrease that could be interpret as chlorophyll-a concentration increasing by standard algorithms

Possible solutions: analyze days only before and after aerosol events or use cross-correlation analysis

3. Interpretation of chlorophyll-a concentration increasing observed by satellite during tropical cyclone passage

It is hard to distinguish case of phytoplankton layer upward and phytoplankton concentration increasing itself due to increasing of nutrients from deeper layers

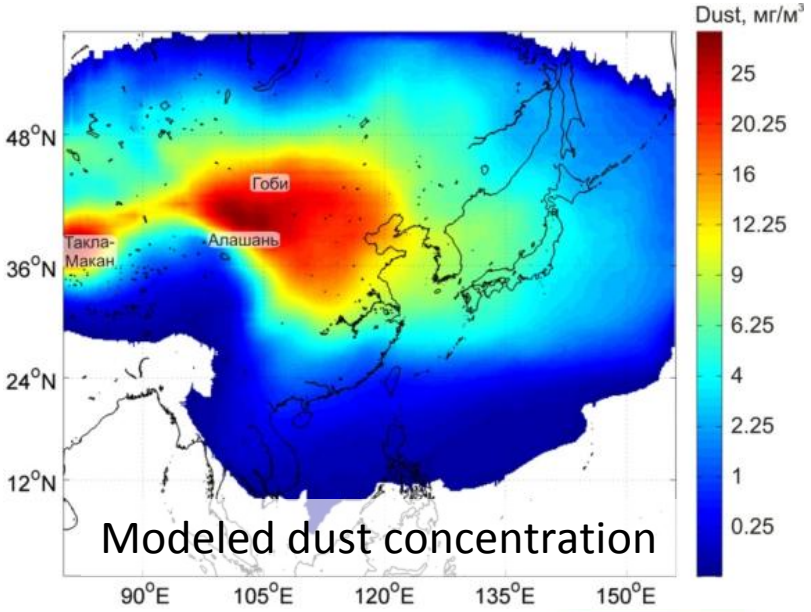
Possible solution: Also analyze sea-surface temperatures time series and use models of vertical phytoplankton distribution, use multi-channel remote sensing of ocean color

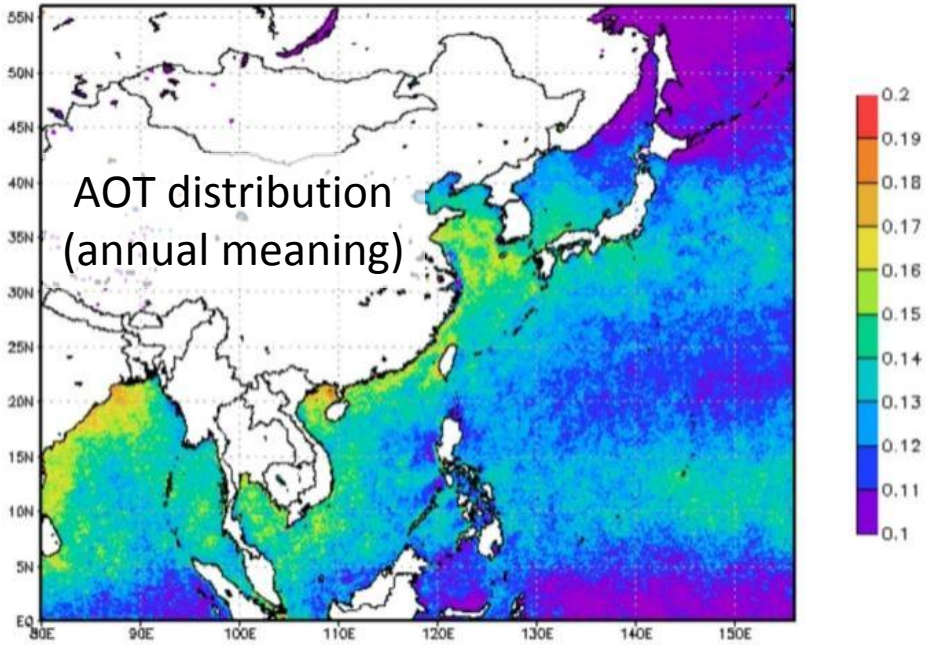
4. Big errors of absolute values retrieved from satellite

Indeed it is not very big problem if relative changes are analyzed

Common solution: use under-satellite measurements

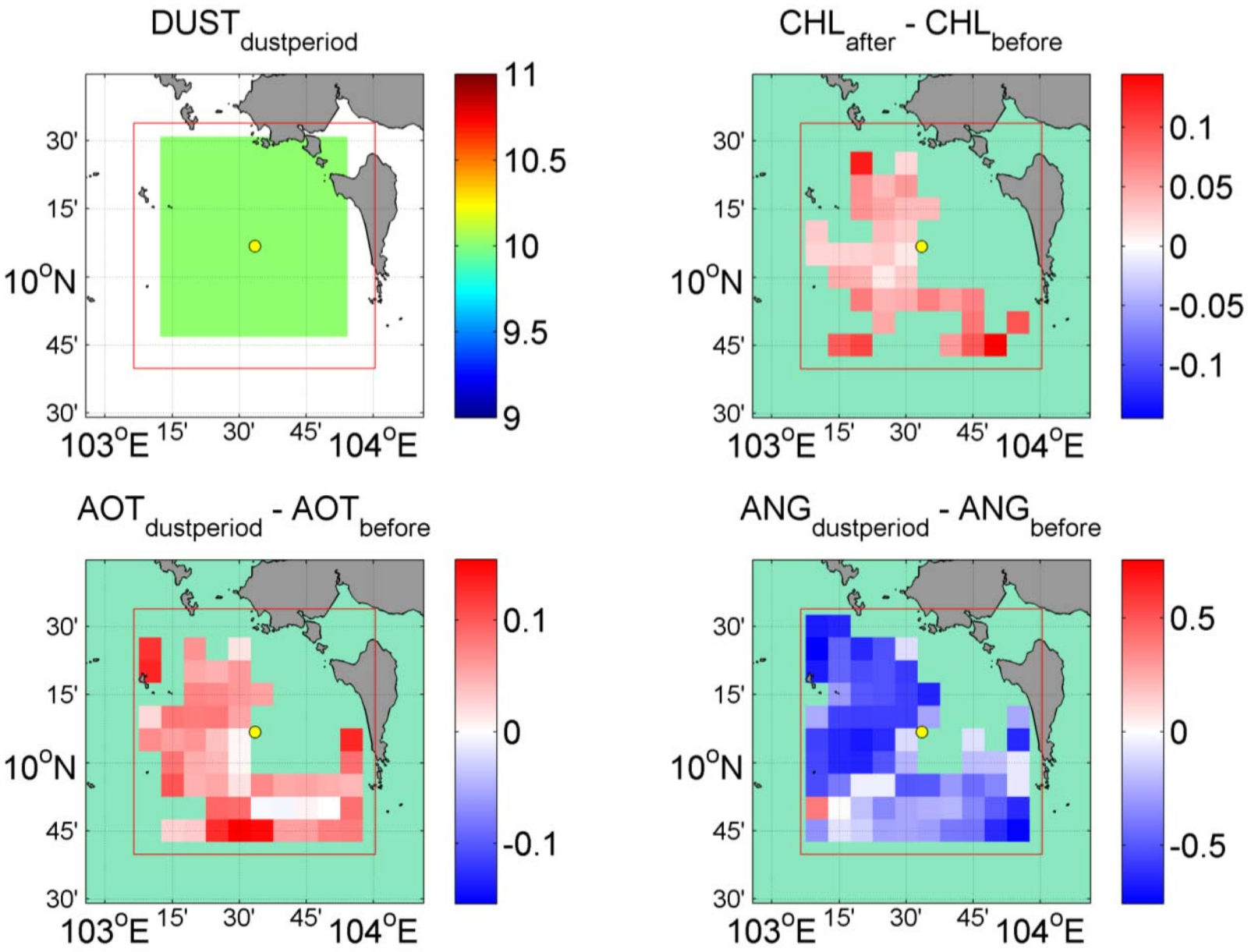
ASIAN DUST STORMS



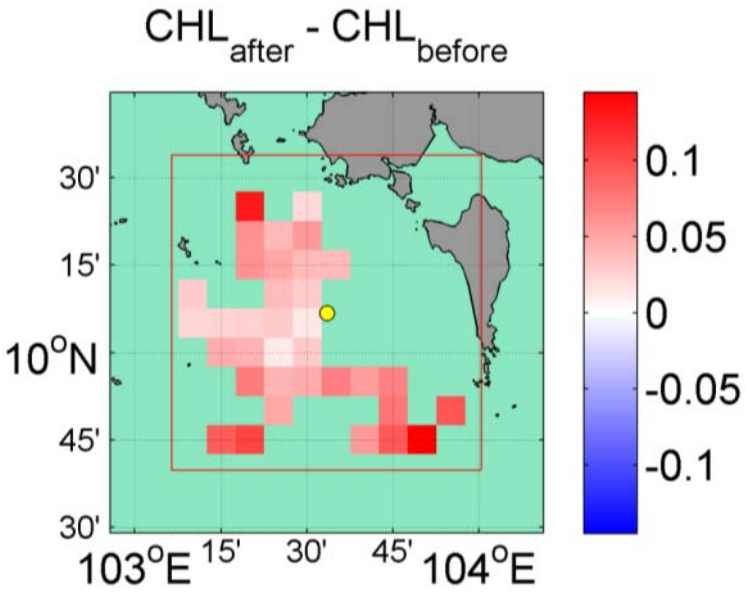


- Increasing of dust aerosol in atmosphere
- Increasing of temperature in troposphere
- Decreasing of temperature in near the Earth surface atmosphere layers
- Increasing of nutrients in the upper ocean layer
- Possible increasing of chlorophyll-a concentration?

Determination of dust event



Regions of 100 km^2 used for the analysis



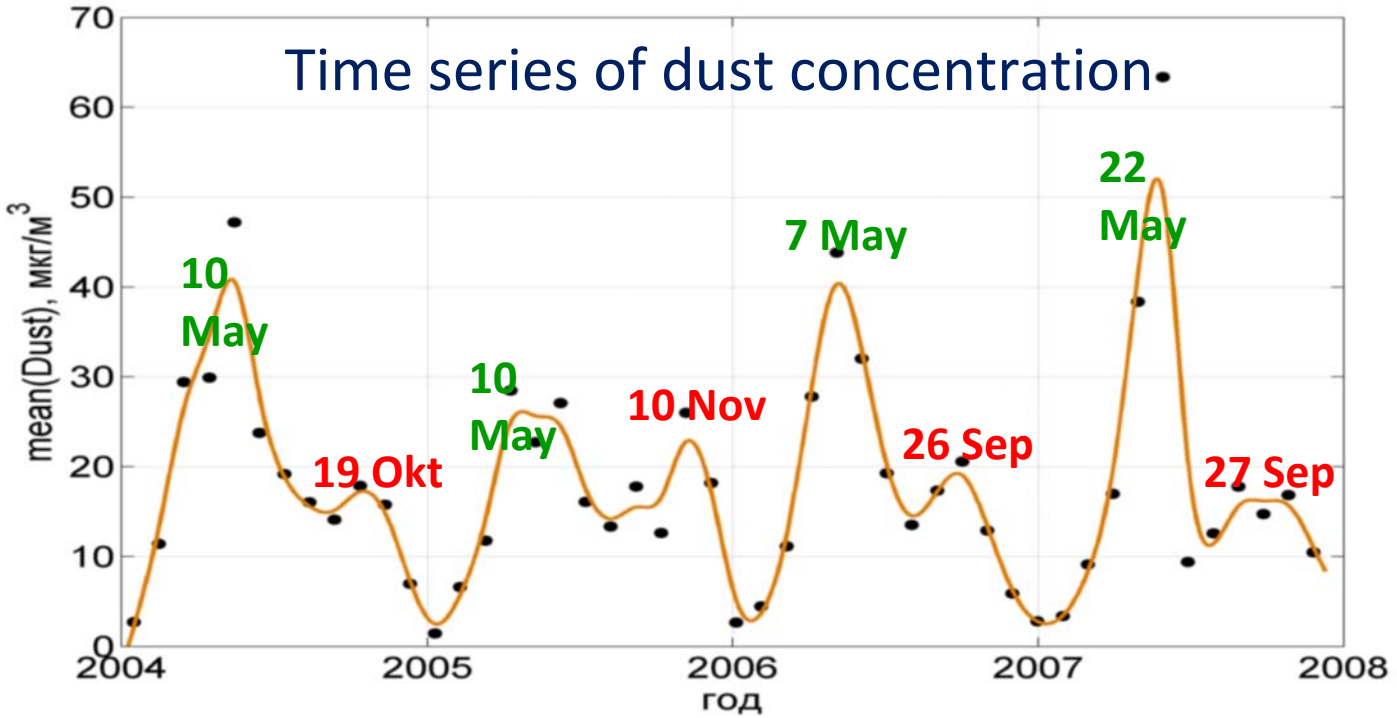
$$C_{before} = C_{before}^{observed} - C_{before}^{season}$$

$$C_{after} = C_{after}^{observed} - C_{after}^{season}$$

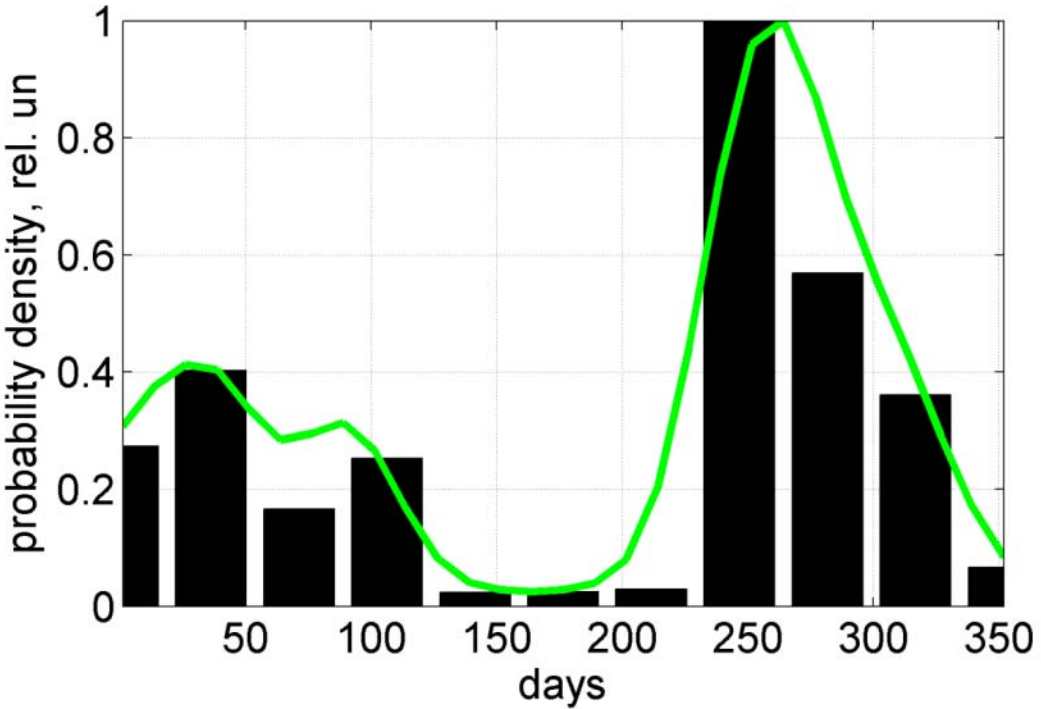
$$\Delta C_r = \frac{C_{after} - C_{before}}{C_{before}} \cdot 100\%$$

100 km^2 areas satisfies following conditions:

- 30 no dust days before considered dust event
- 10 no dust days after considered dust event
- availability of satellite data for 66% of area before and after dust event
- minimum 33 correct data pixels of equal position before and after dust event

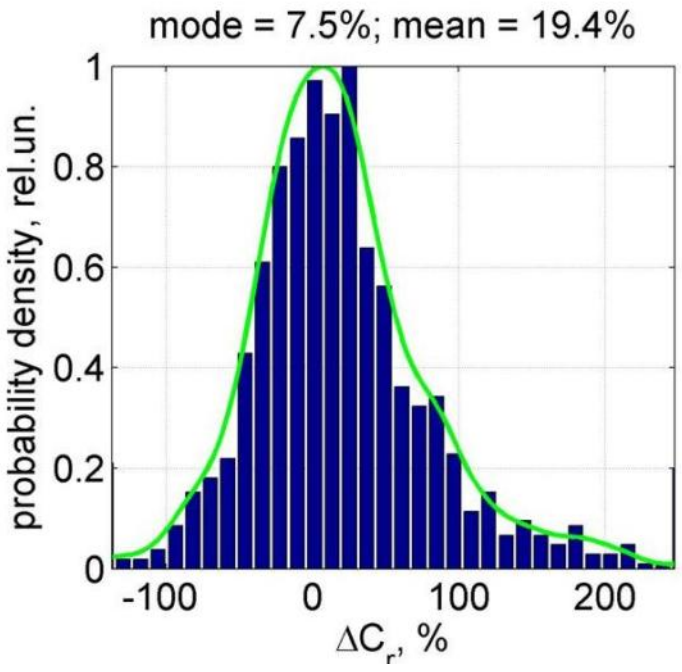


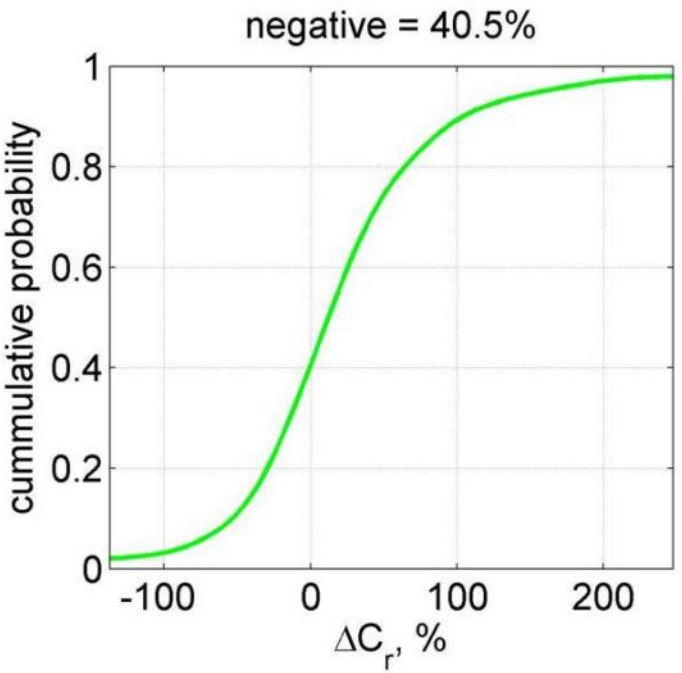
Probability distribution function of days of considered individual dust events

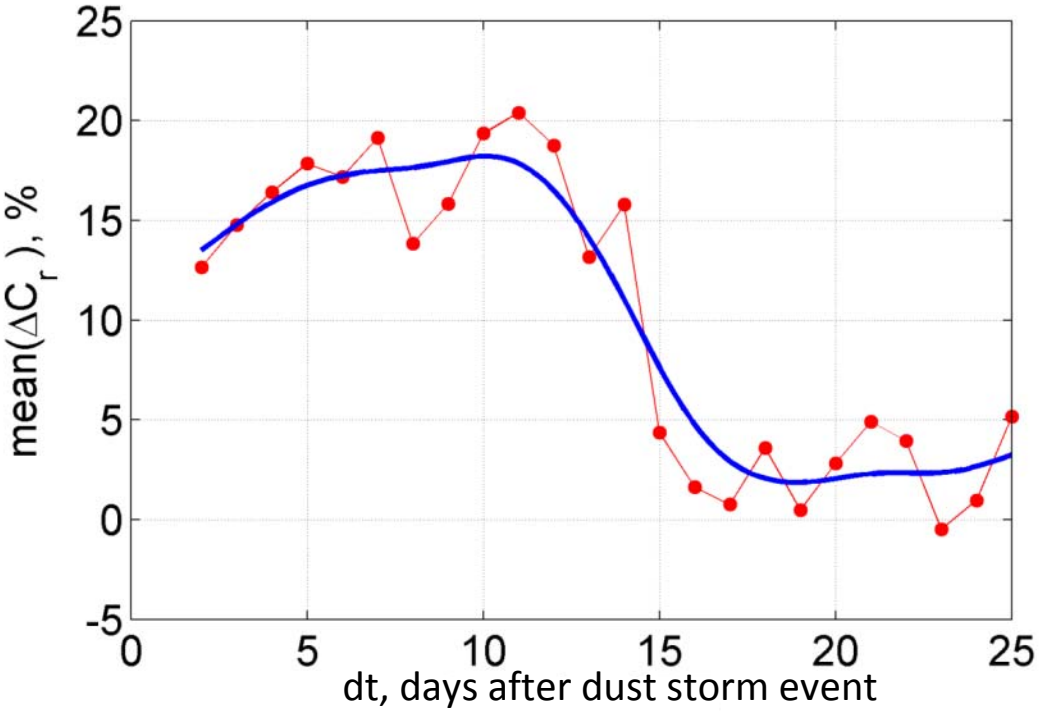


Chlorophyll-a concentrations changes analysis

N = 1760



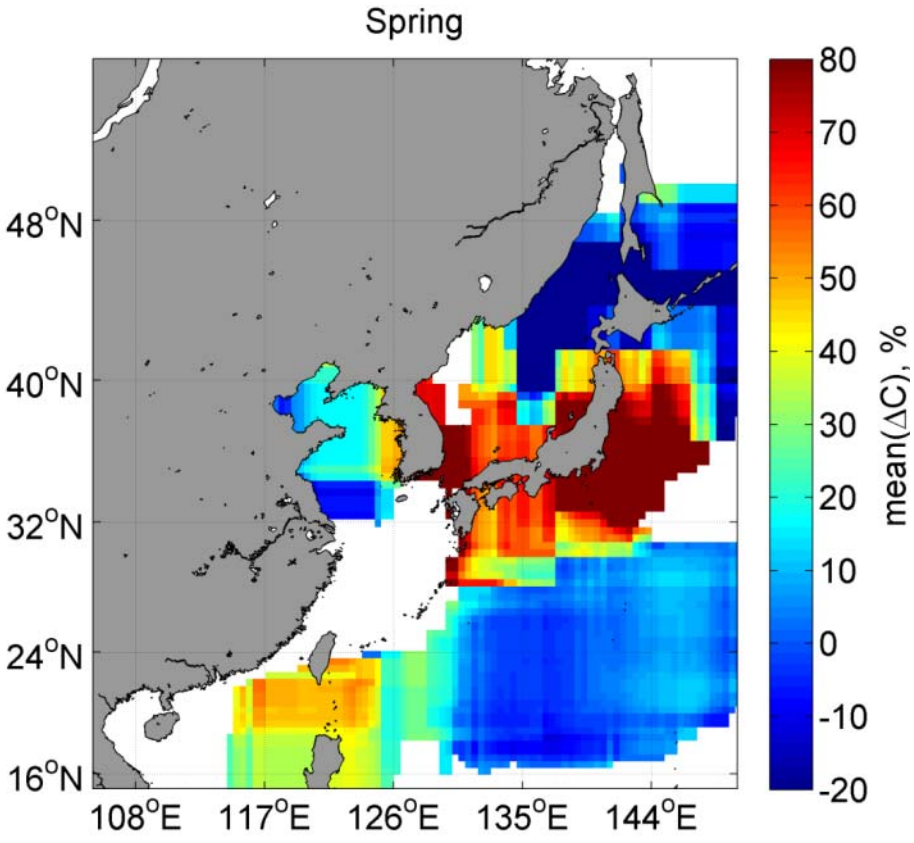


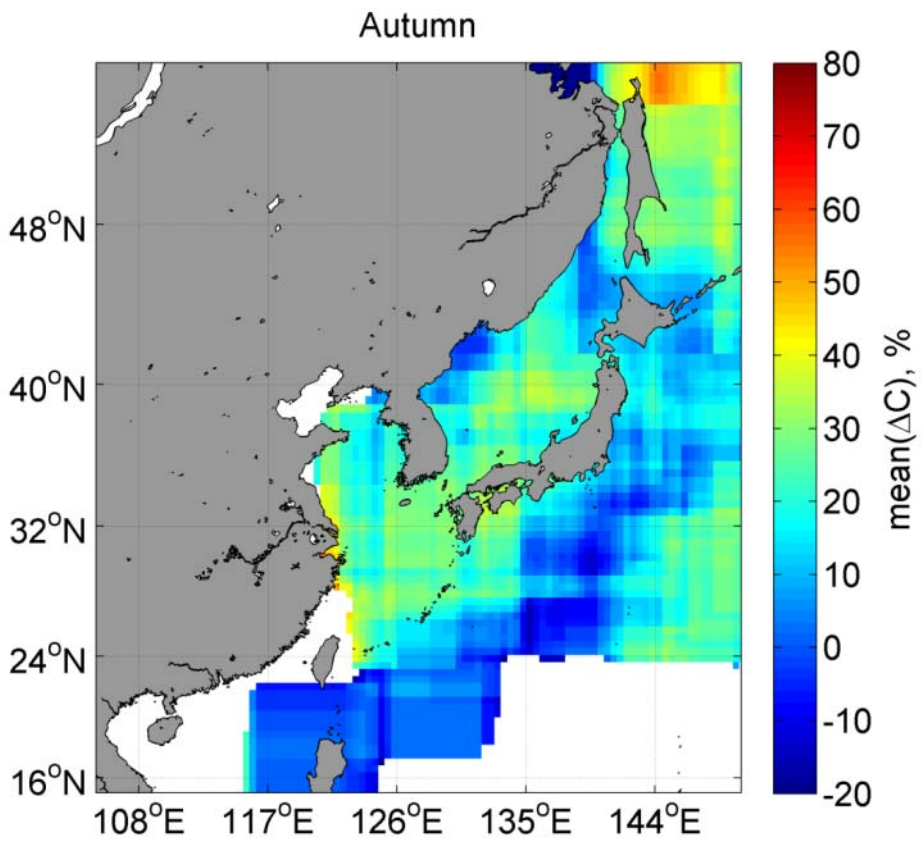


Dust storms not necessary lead to phytoplankton concentration increasing. It depends on:

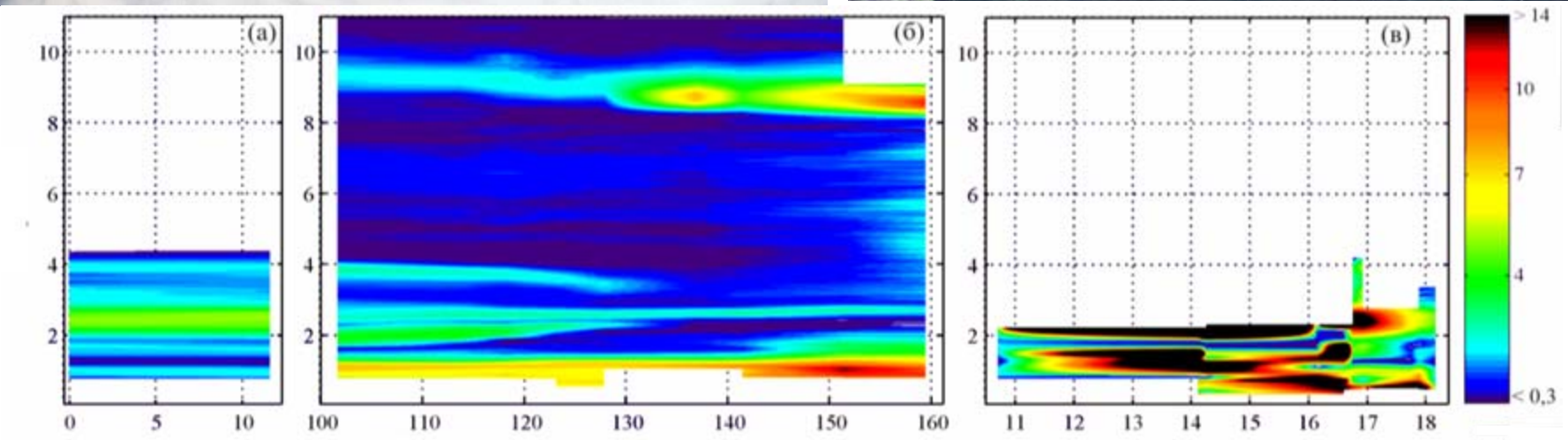
- Aerosol chemical composition
- Limiting factors of phytoplankton growth
- Phytoplankton species

Analysis of spatial distribution of chlorophyll-a concentration changes





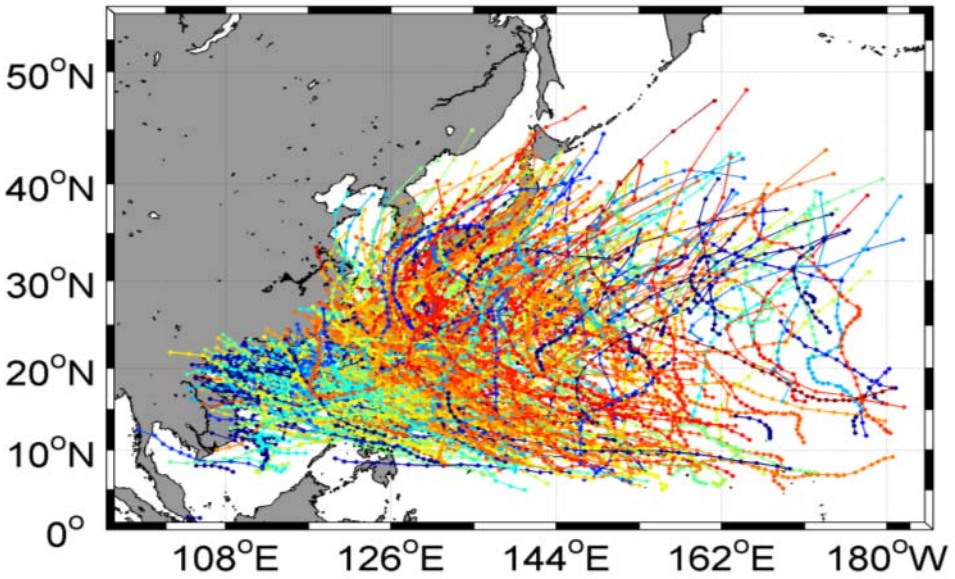
VOLCANIC ERUPTIONS



Increasing of stratosphere and troposphere aerosol, aerosol falls at sea surface
Increasing of temperature in atmosphere, decreasing of surface temperature

TROPICAL CYCLONES

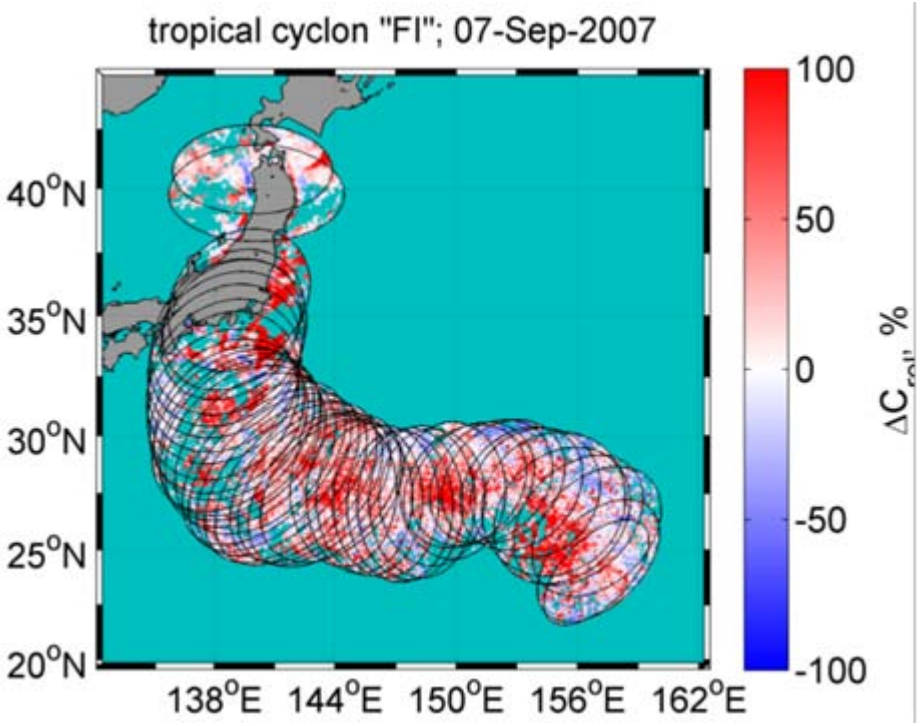
TC tracks during satellite era



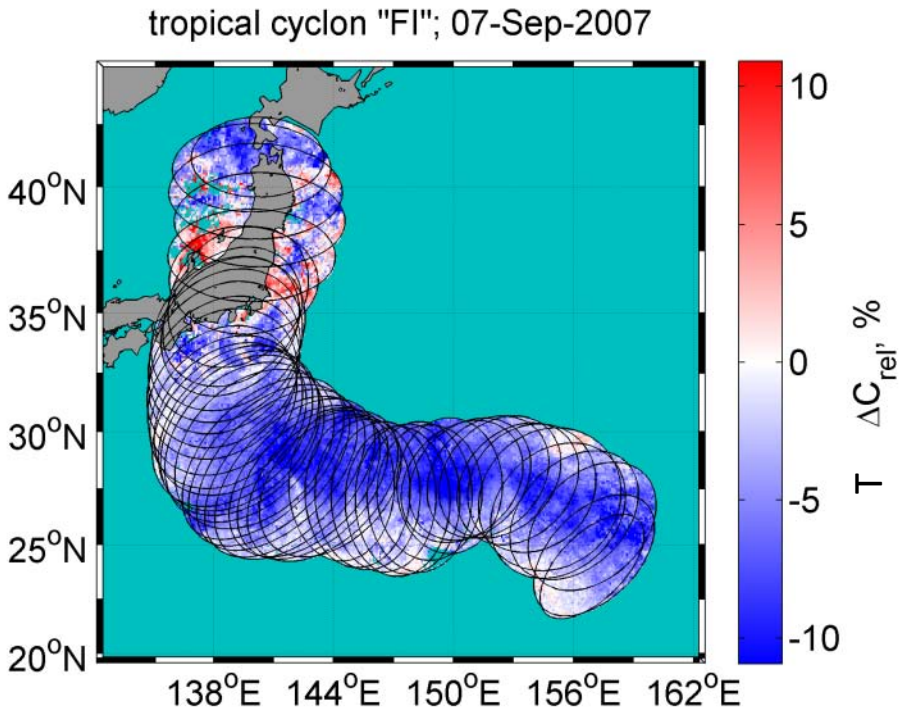
- Increasing of clouds and troposphere aerosol
- Decreasing of surface temperature
- Upward of phytoplankton to the sea surface
- Upward nutrients and organic matters to upper layers
- Increasing of phytoplankton concentrations

Example of tropical cyclone influence on upper ocean layer

Chlorophyll-a increasing



Temperature decreasing

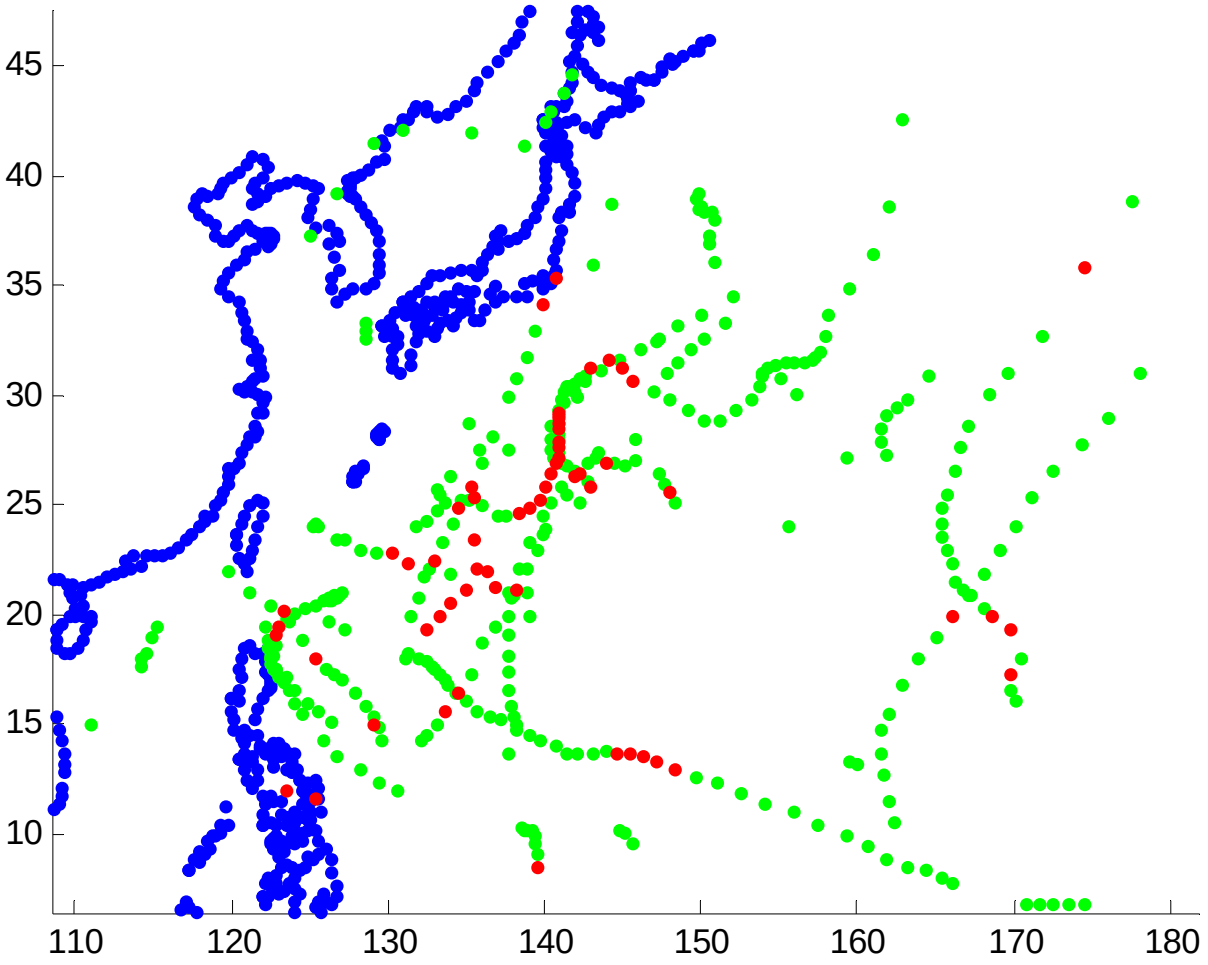


There are following conditions for the analysis:

- significant statistics of correct satellite data in the same pixels before and after tropical cyclone
- minimum wind speed of 30 knots
- no one other tropical cyclones before 30 days and after 10 days of considered cyclone

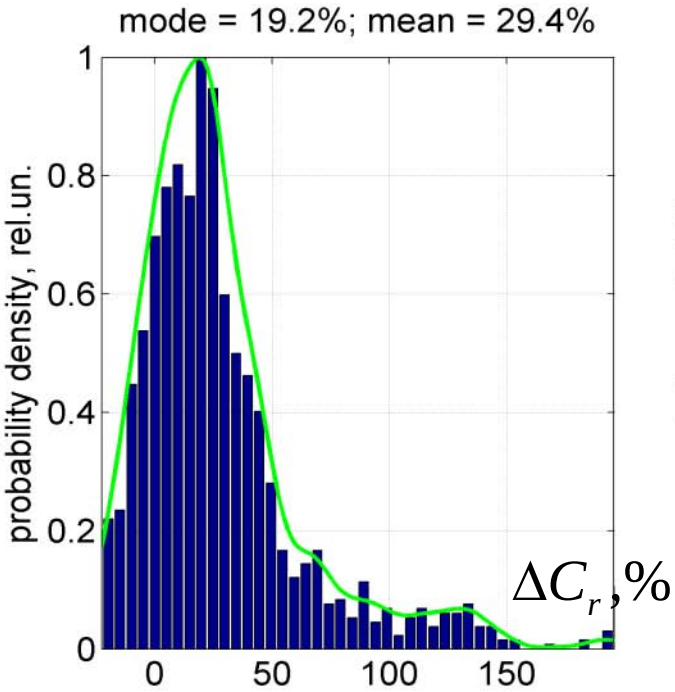
DISTRIBUTION OF REGIONS SELECTED FOR THE ANALYSIS

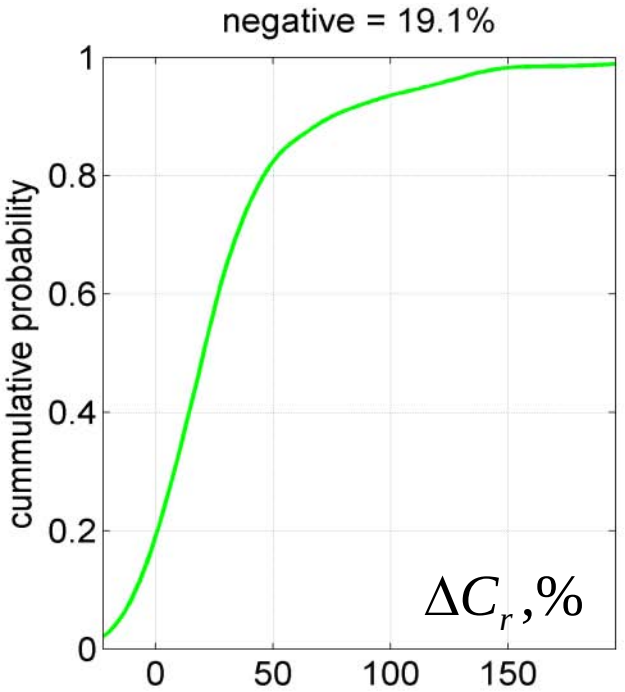
Subtotal **1389** regions for chlorophyll-a and **1414** for temperature changes analyses



Satellite observed chlorophyll-a concentration changes

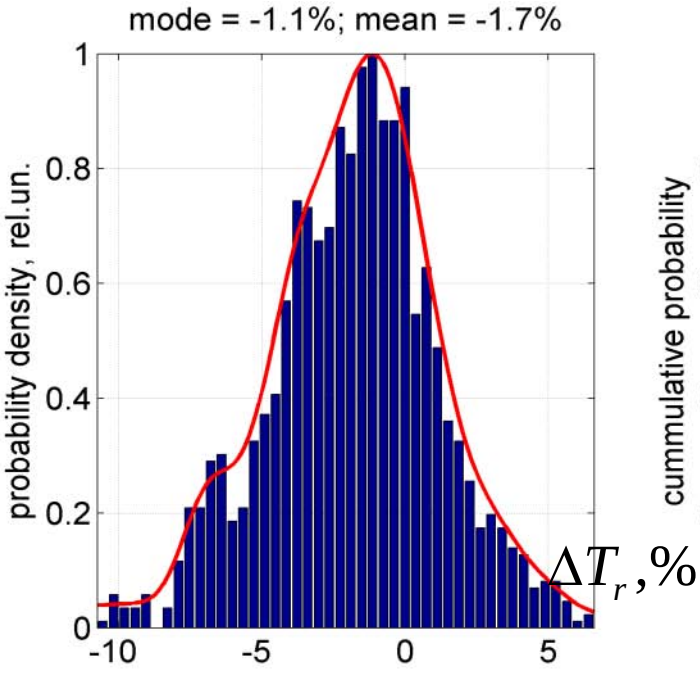
N = 1389

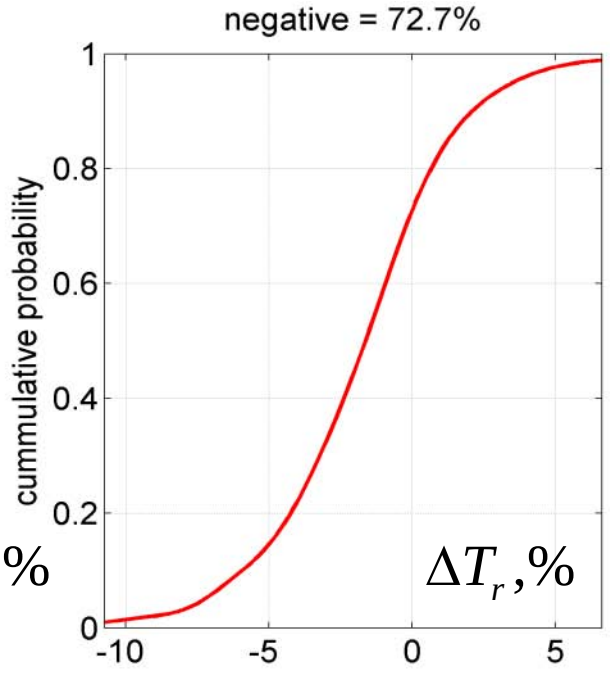




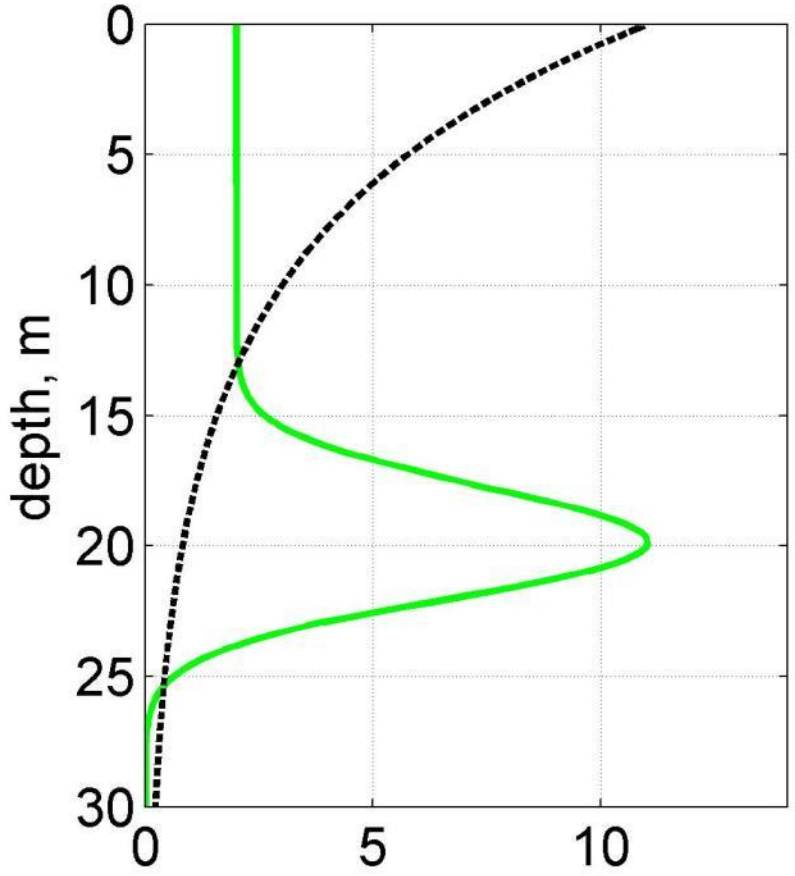
Satellite observed Sea-surface temperatures changes

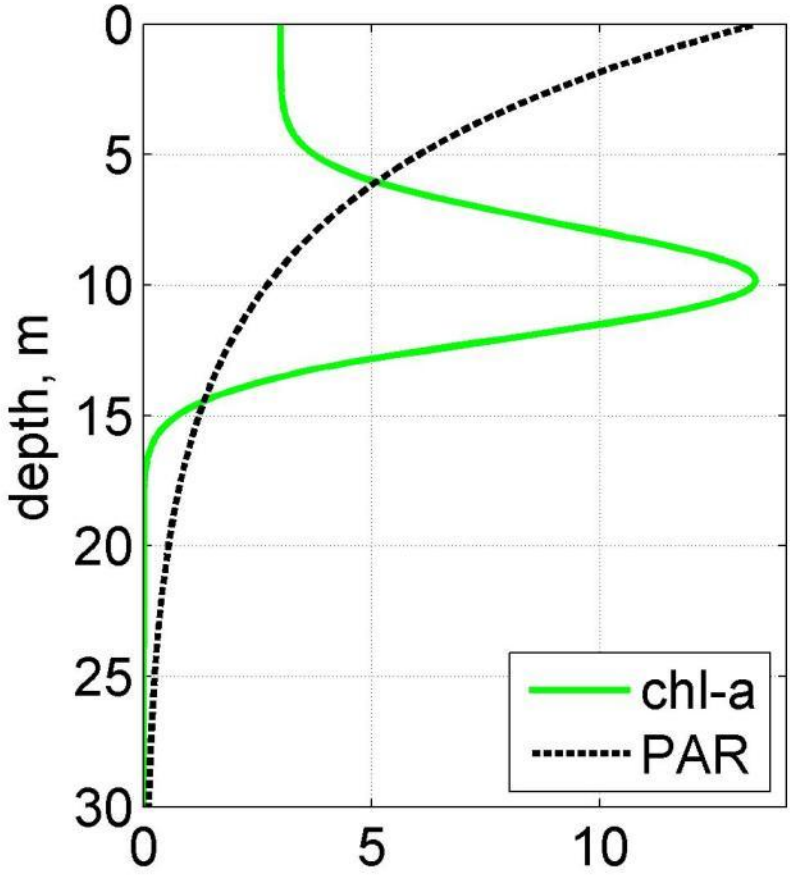
N = 1414





Upward of phytoplankton layer or increasing of phytoplankton concentration?



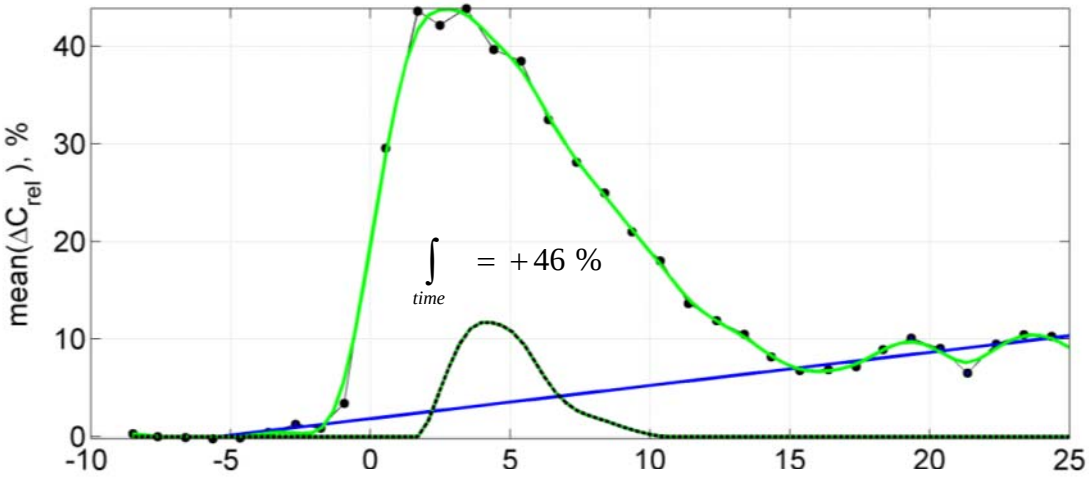


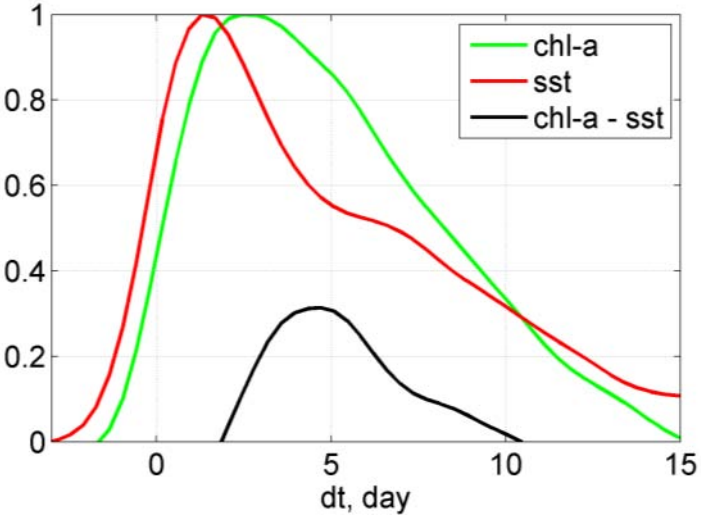
$$\sum C_{after} = \sum C_{before}$$

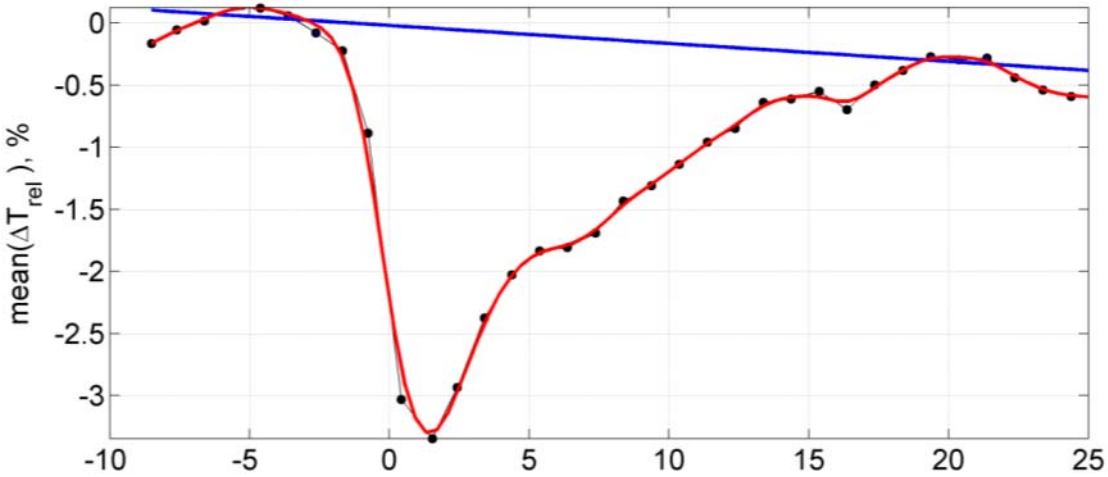
$$\sum C_{after}^{sat.view} > \sum C_{before}^{sat.view}$$

Increasing of total photosynthesis efficiency and CO2 uptake

TIME SERIES OF CHLOROPHYLL-A AND TEMPERATURE RELATIVE CHANGES







ANALYSIS OF GLOBAL INFLUENCE OF DUST STORMS AND TROPICLA CYCLONES IN THE NORTH-WESTERN PACIFIC

We have:

- estimations of integral increasing of chlorophyll-a concentration due to dust storms and tropical cyclones passage
- Spatial-temporal distributions of regions are impacted by dust storms and tropical cyclones
- Climate data of chlorophyll-a spatial-temporal distributions

So we can obtain roughly estimations of
Additional mass of chlorophyll-a which used for photosynthesis in a year:
0.5-2* Pg of chl-a in a year for tropical cyclones
0.2-0.5* Pg of chl-a in a year for dust storms (but it is hard to count all dust events)
(*if set the 10 meter depth of phytoplankton concentration changes)

Conclusion
Dust storms and tropical cyclones are significant stimulators of phytoplankton growth in the North-western Pacific


Thank you for
your kindly
attention