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Development and calibration of GCOM-C ocean algorithms to derive marine biogeochemical and ecological variables towards satellite-model integrated analysis

T. Hirata
(Hokkaido University)

JAXA GCOM-C PI meeting,
TKP GardenCity Tokyo,
15 Jan 2014

JAXA Japan Aerospace Exploration Agency

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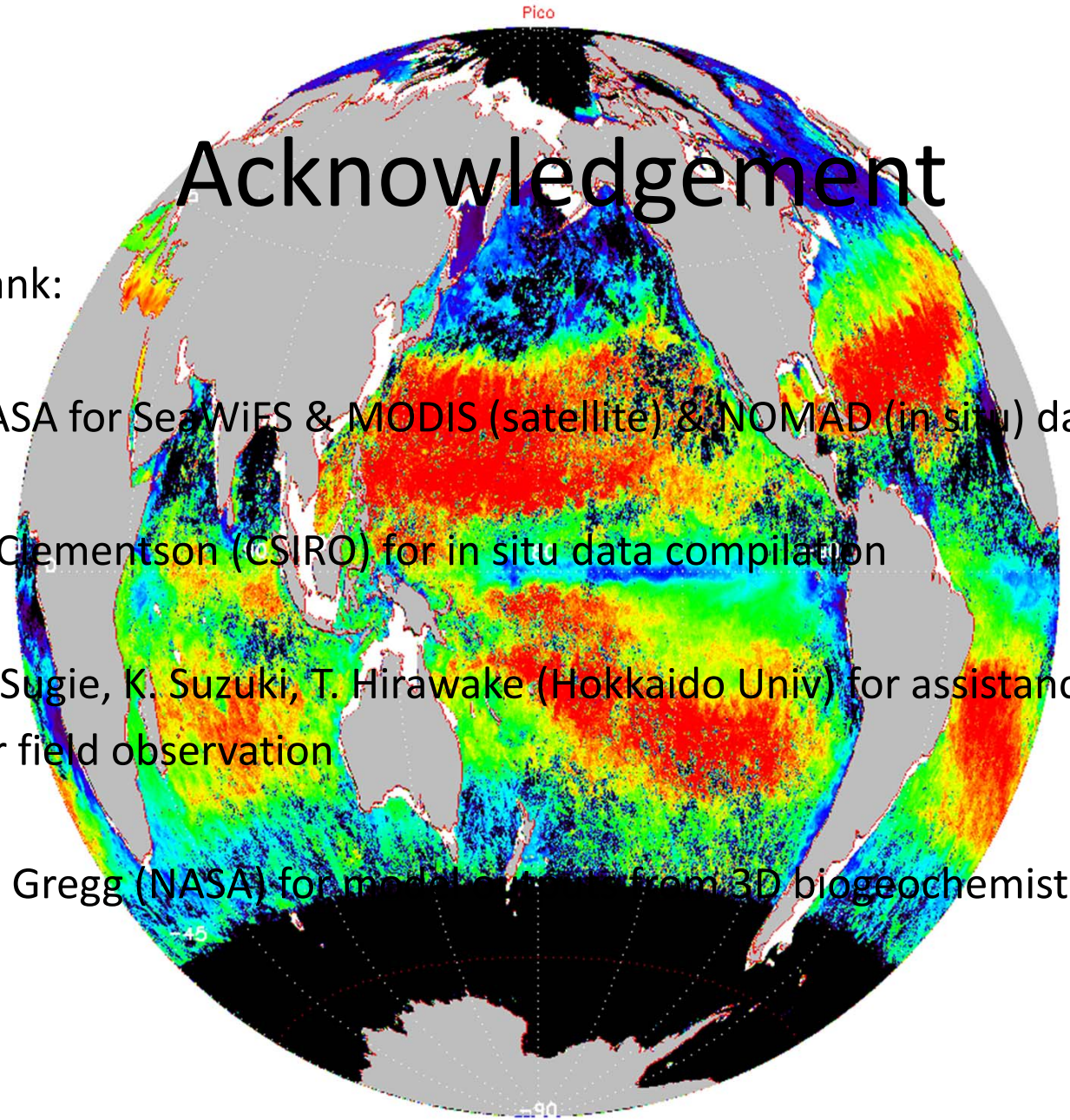
Acknowledgement

We thank:

- NASA for SeaWiFS & MODIS (satellite) & NOMAD (in situ) data
- L. Clementson (CSIRO) for in situ data compilation
- K. Sugie, K. Suzuki, T. Hirawake (Hokkaido Univ) for assistance for field observation
- W. Gregg (NASA) for [illegible] from 3D biogeochemistry model



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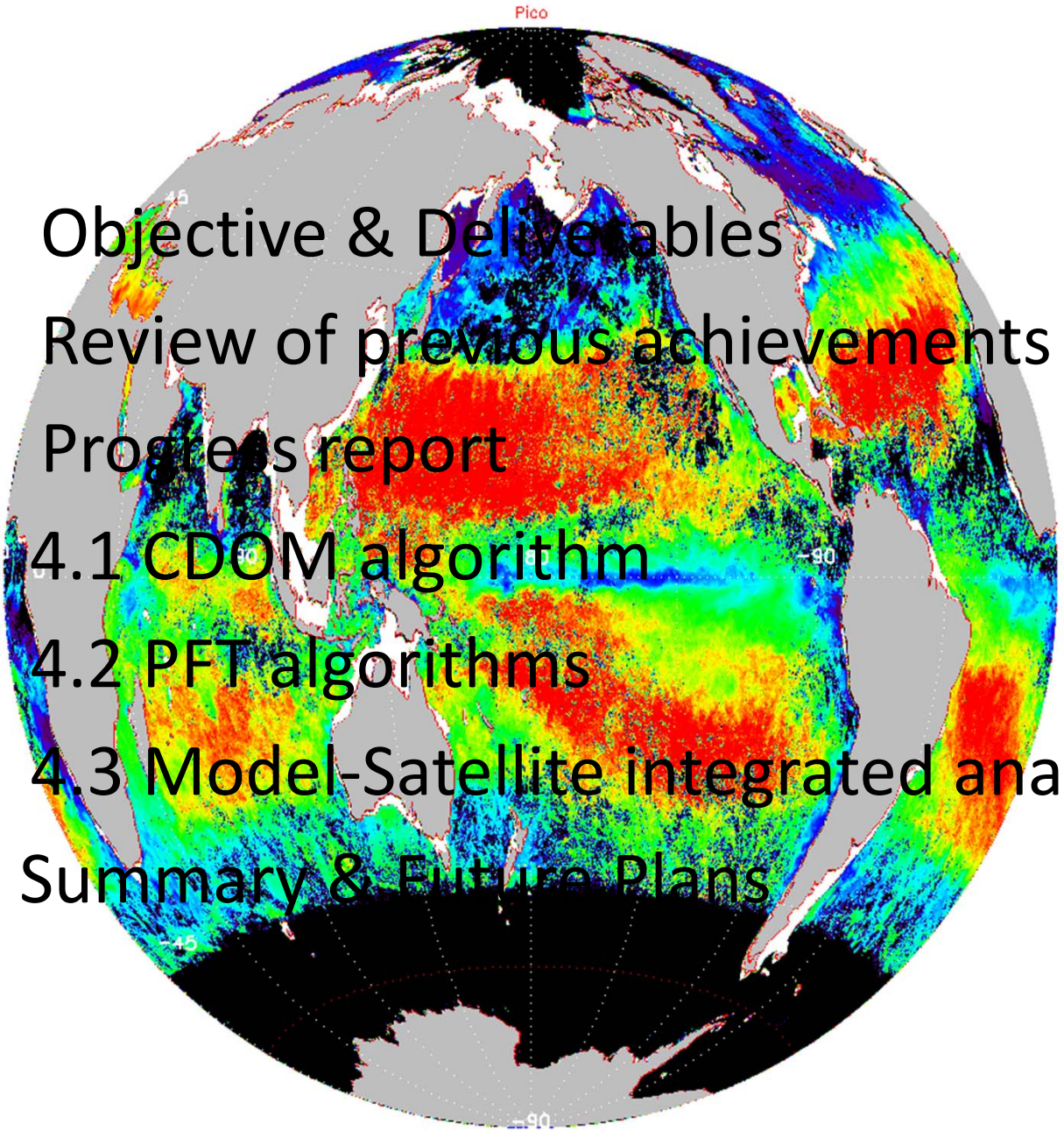
Contents



1. Objective & Deliverables
2. Review of previous achievements
3. Progress report
   - 4.1 CDOM algorithm
   - 4.2 PFT algorithms
   - 4.3 Model-Satellite integrated analysis
4. Summary & Future Plans

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1. Objective & Deliverables

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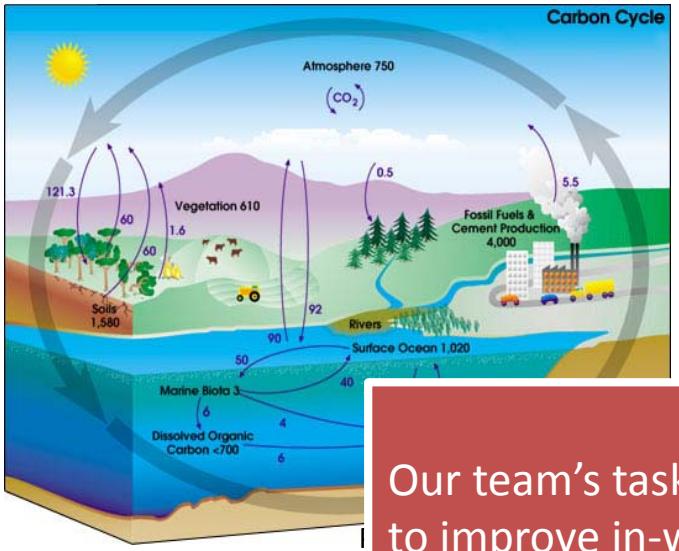

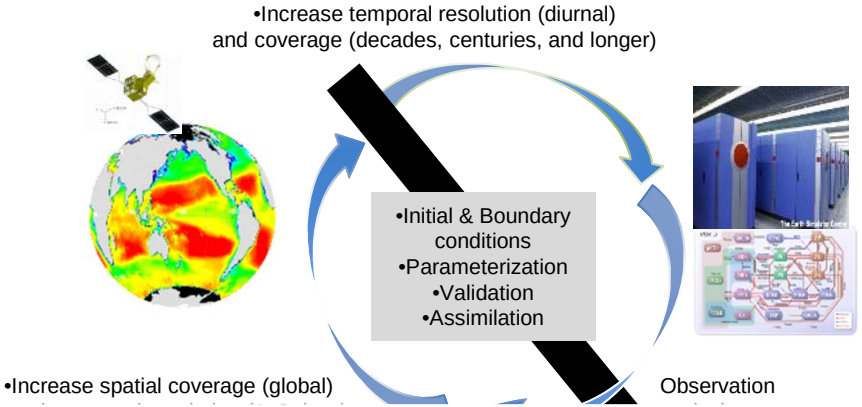

Our team's task in this and next couple of years is to improve in-water algorithms developed in previous years

GCOM OBJECTIVE: GCOM se tial geophysical parameters for understanding global climate change and carbon and water cycles (Quoted from GCOM-C RA4 document)

Deliverables from our team:

(1) An optimized algorithm to derive marine Coloured Dissolved Organic Matter index (CDOM), or the optical absorption coefficient of CDOM (STANDARD PRODUCT)

(2) In situ measurement protocol for CDOM product validation

(3) An optimized algorithm to derive the Inherent Optical Properties (IOPs) (RESEARCH PRODUCT)

(4) Optimized satellite algorithms to derive Phytoplankton Functional Types (PFTs) (RESEARCH PRODUCT)

(5) Results of development of, and analysis by, a marine biogeochemistry/ecosystem model which includes optical characteristics/processes using satellite ocean colour data

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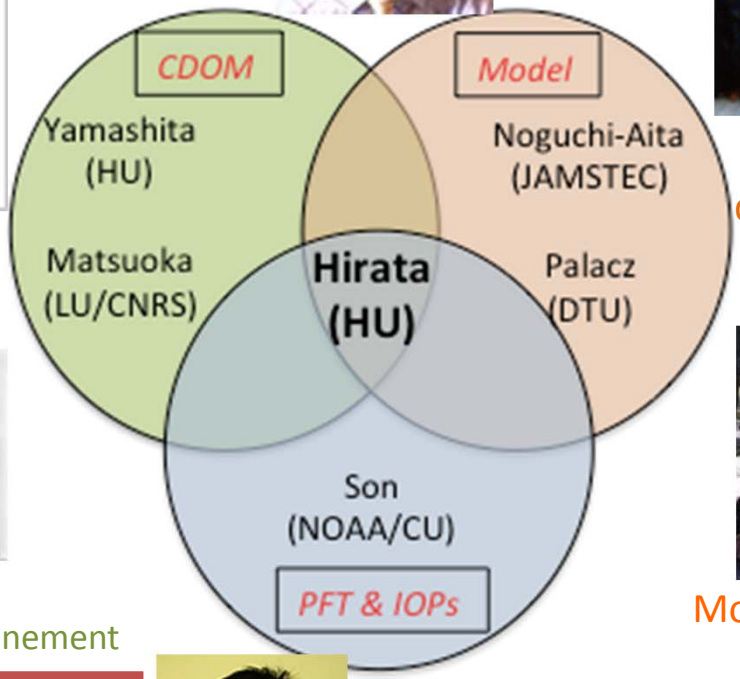
1. Objective & Deliverables

PI

CDOM group

In situ Protocol

Algorithm Development/refinement



Model group

Model development

Model Analysis

40% female, 60% male
50% international
90% < 45 y.o.

HU: Hokkaido University (Japan)
JAMSTEC: Japan Agency for Marine-Earth Science and Technology (Japan)
LU: Laval University (Canada)
CNRS: National Centre for Scientific Research (France)
DTU: Technical University of Denmark (Denmark)
NOAA: National Oceanic and Atmospheric Administration (USA)
CU: Colorado University (USA)

PFT/IOP group, Analysis

Technician@HU

Sato (HU)

Other Collaborators :

Bracher (Bremen U, Alfred Wegener Institute, Germany) (PFT)

Soppa (Bremen U, Alfred Wegener Institute, Germany) (PFT)

Hardman-Mountford (CSIRO, Australia) (PFT)

Hirata:
- Overall management (PFT/IOP algorithm refinement, CDOM algorithm refinement, Model-Satellite integrated analysis)

Yamashita
- Protocol for in situ CDOM

Matsuoka
- Algorithm development & refinement

Noguchi-Aita
- PFT model development

Palacz:
- Integrated analysis

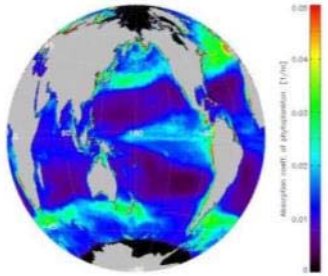
Son:
- PFT/IOP analysis

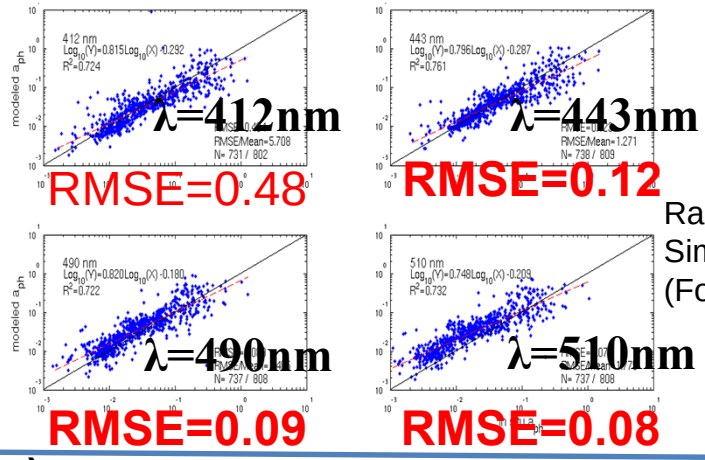
2. Review of previous achievements

A.1 Phytoplankton

Target Accuracy **RMSE 0.25**

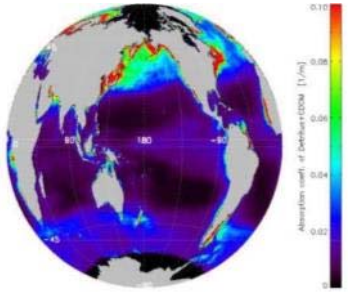
Validation using other satellite data (**SeaWiFS**): **NASA is acknowledged for SeaWiFS and NOMAD data**

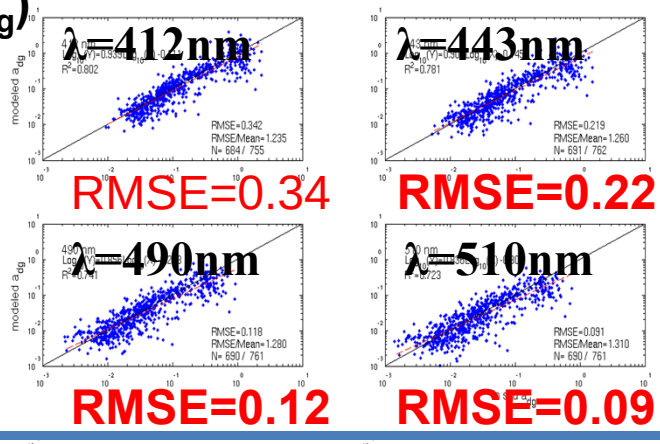




A.2 & A.3 Detritus+CDOM (a_{d+g})

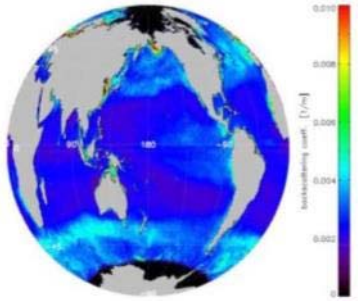
Target Accuracy **RMSE 0.25**

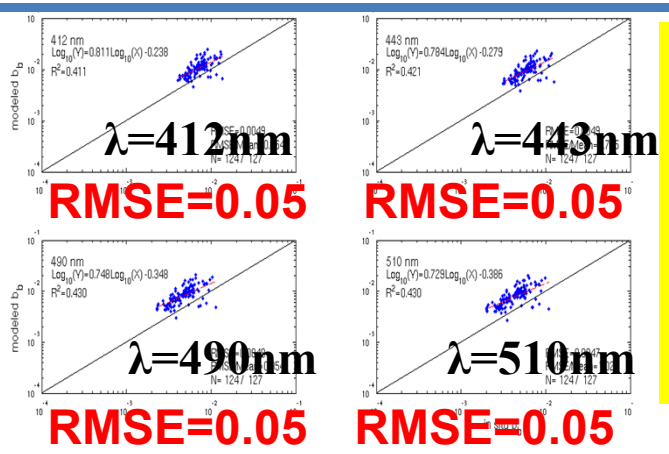


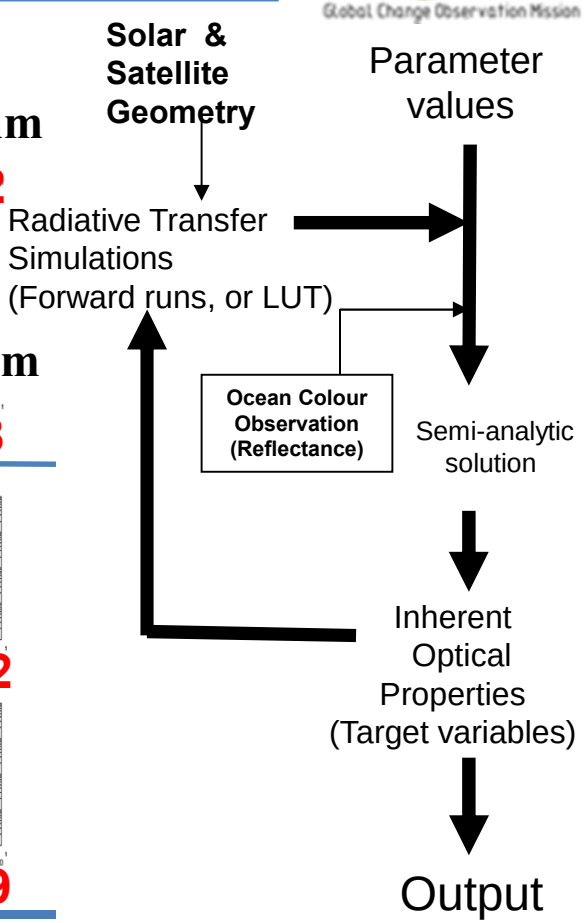


B. Suspended particles

Target Accuracy **RMSE 0.25**





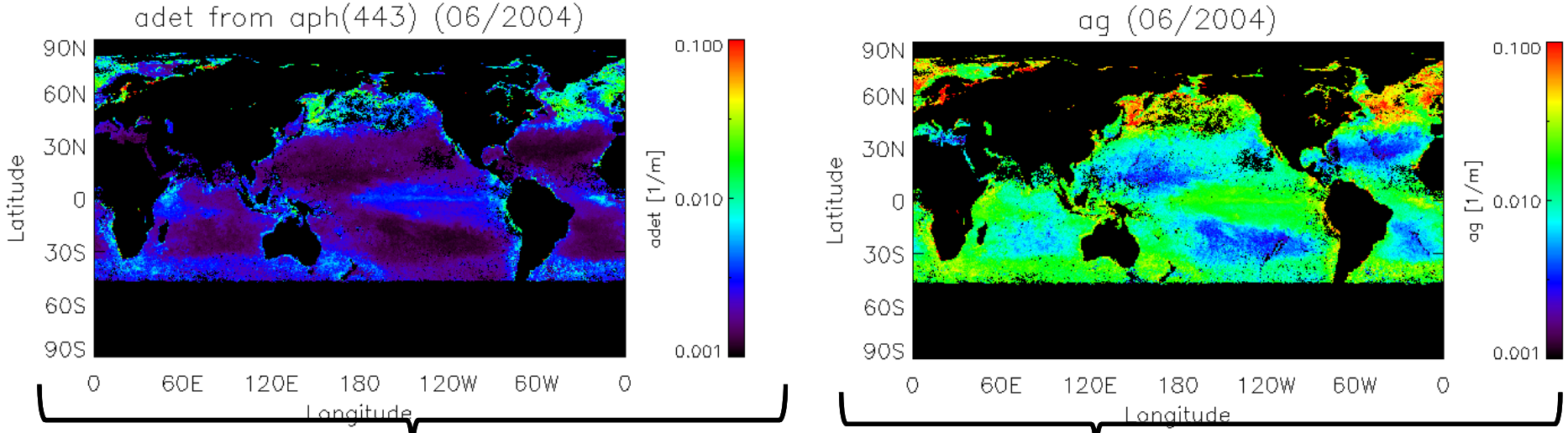


So far, we can get :
(1) The absorption coefficients of Phytoplankton
(2) The backscattering coefficient of hydrosols
(3)The absorption coefficient of CDOM+detritus

Smyth, T, Moore, G., Hirata, T., Aiken, J., 2006

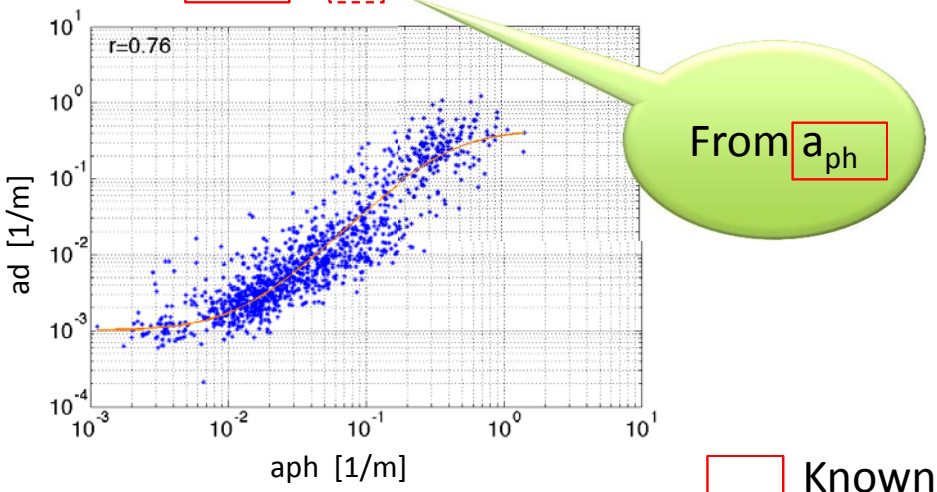
2. Review of previous achievements

Our task is to decompose the absorption coefficient of "detritus + CDOM"(adg) into each components (a_d & a_g)

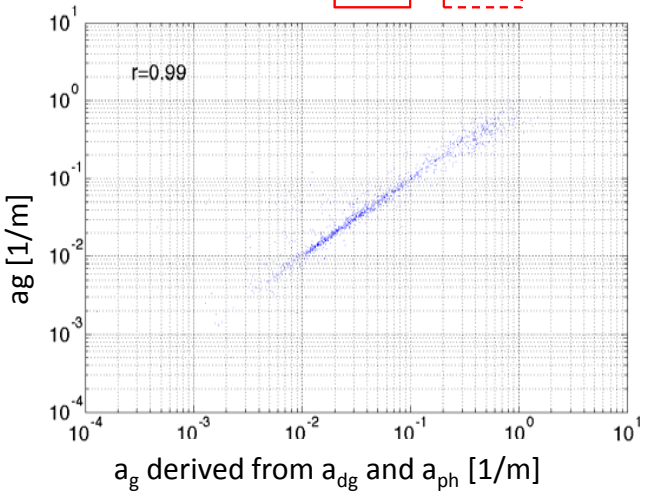


$a_{dg} = a_d + a_g$

$a_g = a_{dg} - a_d$



From a_{ph}



Empirical determination of a_d from a_{ph}

Known

Derive from a known variable

2. Review of previous achievements

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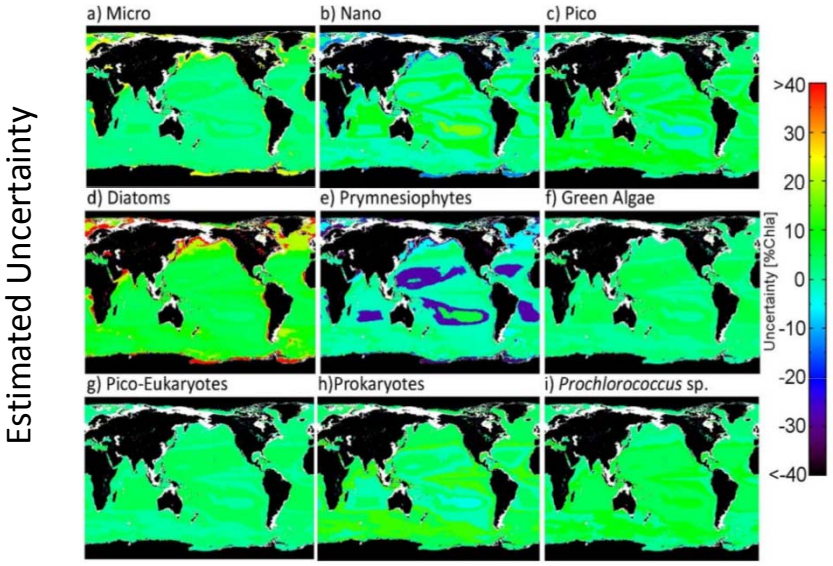
Derive $a_{ph}(443)$ from RS reflectance (OC-PFT ver.1)

Derive Chla from RS reflectance (OC-PFT ver.0)

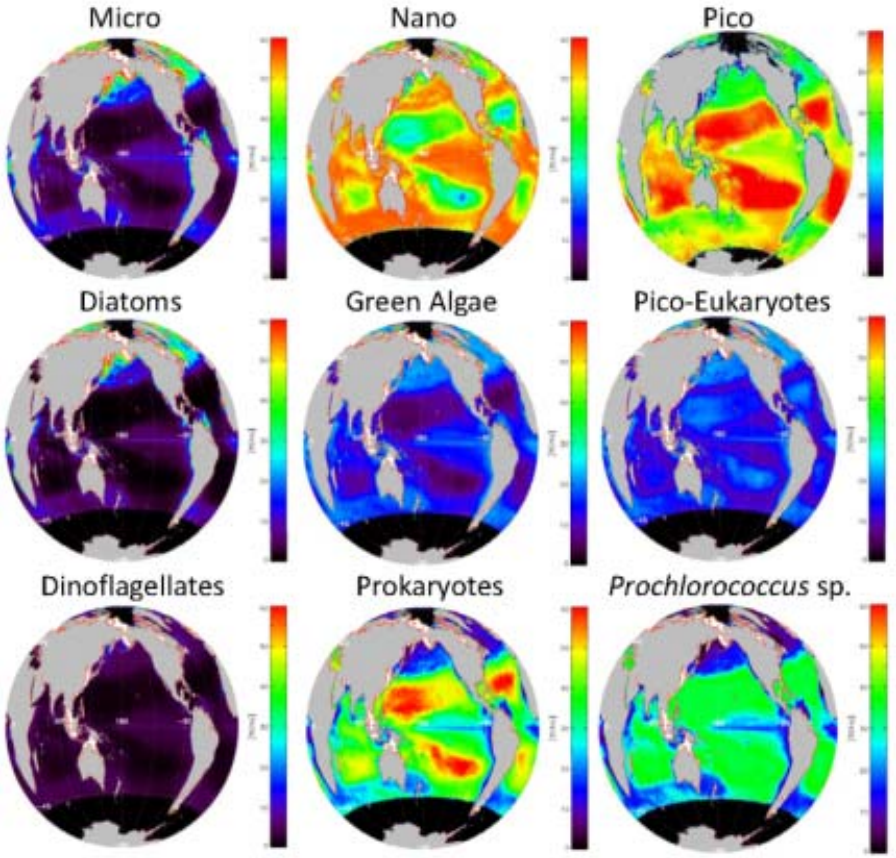
Convert $a_{ph}(443)$ to Chla

Derive PFTs from Chla



We developed algorithms to derive 9 groups of phytoplankton globally

for the first time



GLOBEC INTERNATIONAL NEWSLETTER
A Core Project of the International Geosphere-Biosphere Programme
http://www.globec.org
March 2011 News...
IOCCG International Ocean Colour Coordinating Group

2. Review of previous achievements

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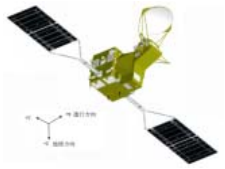
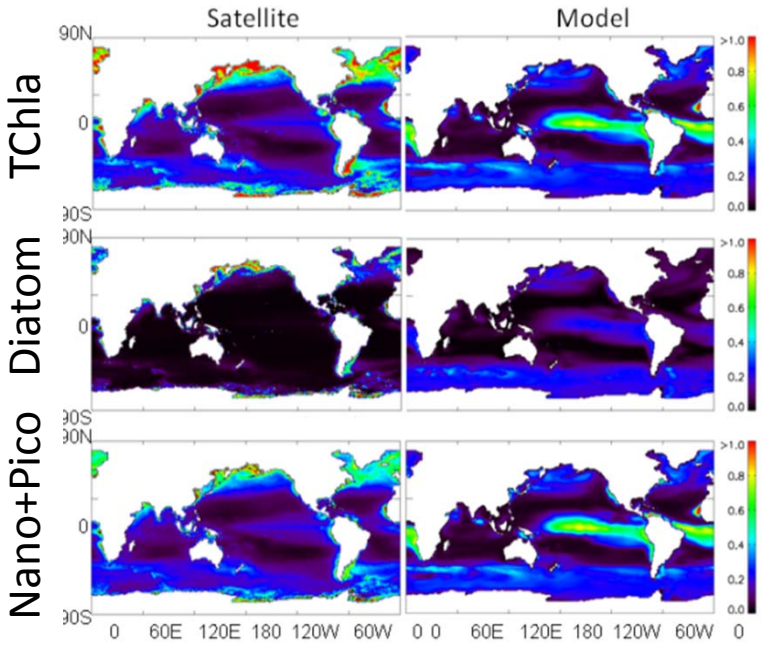
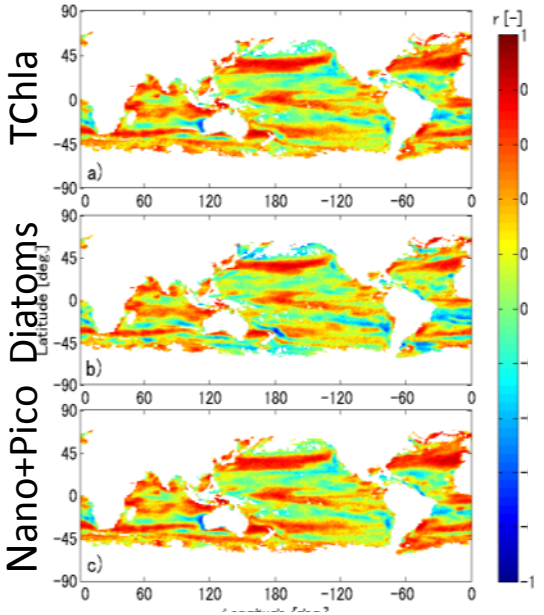


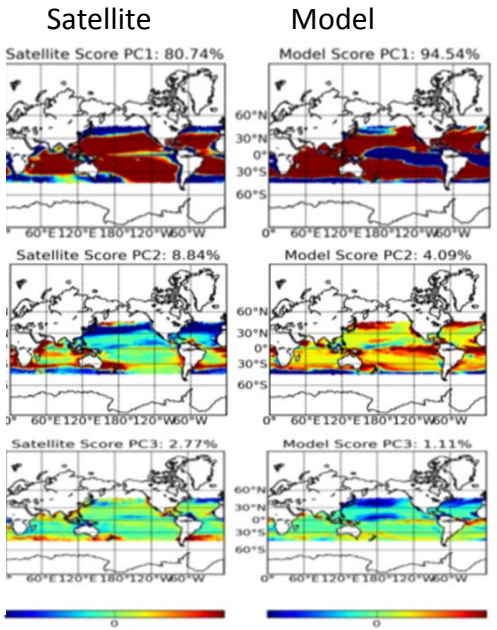
Hirata et al., 2012

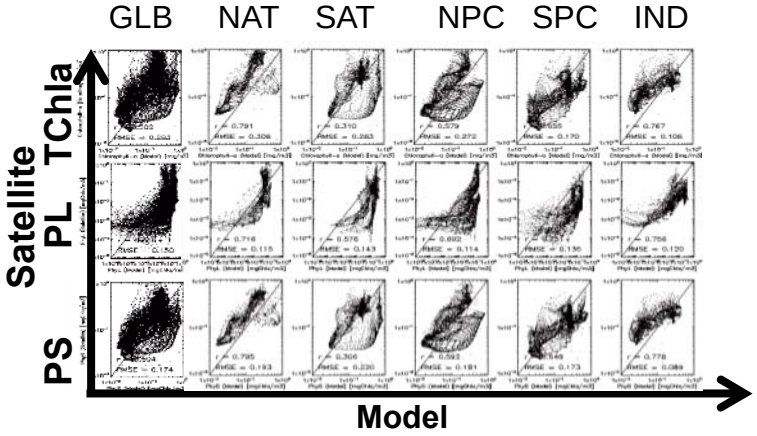


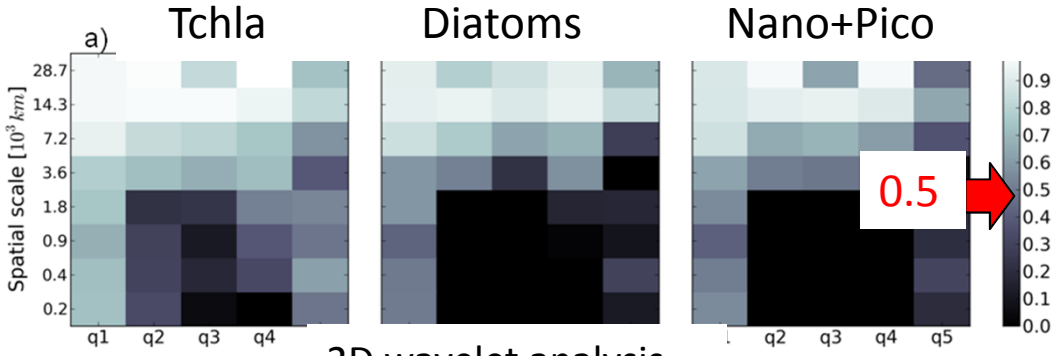
Temporal correlations between satellite and model



Principal Components







2D wavelet analysis

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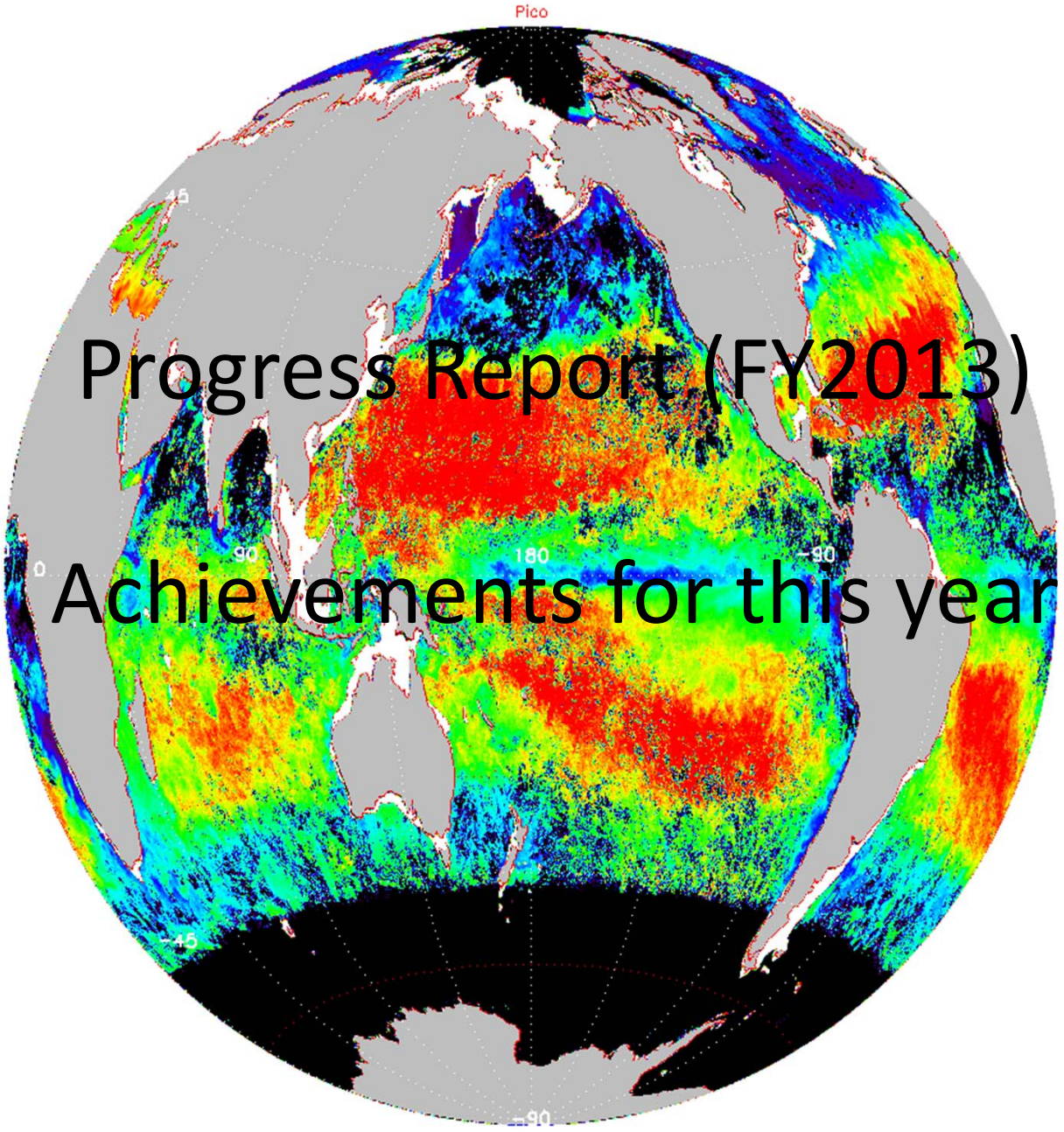

Progress Report (FY2013)

Achievements for this year

4.1 CDOM algorithm

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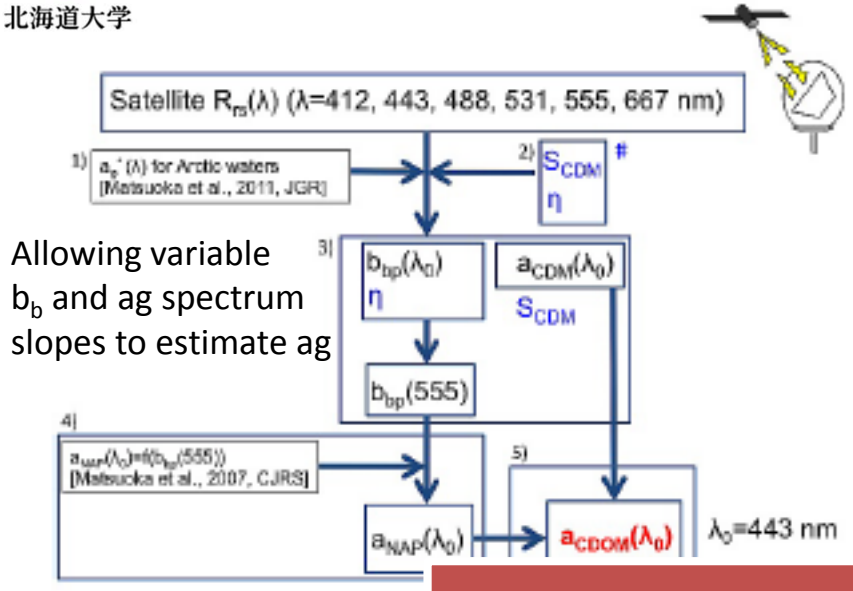
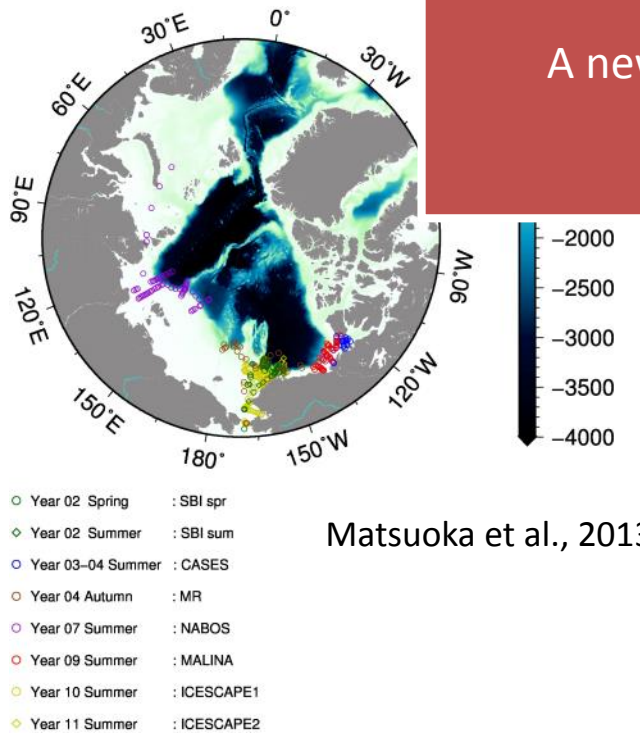


Allowing variable b_b and ag spectrum slopes to estimate ag



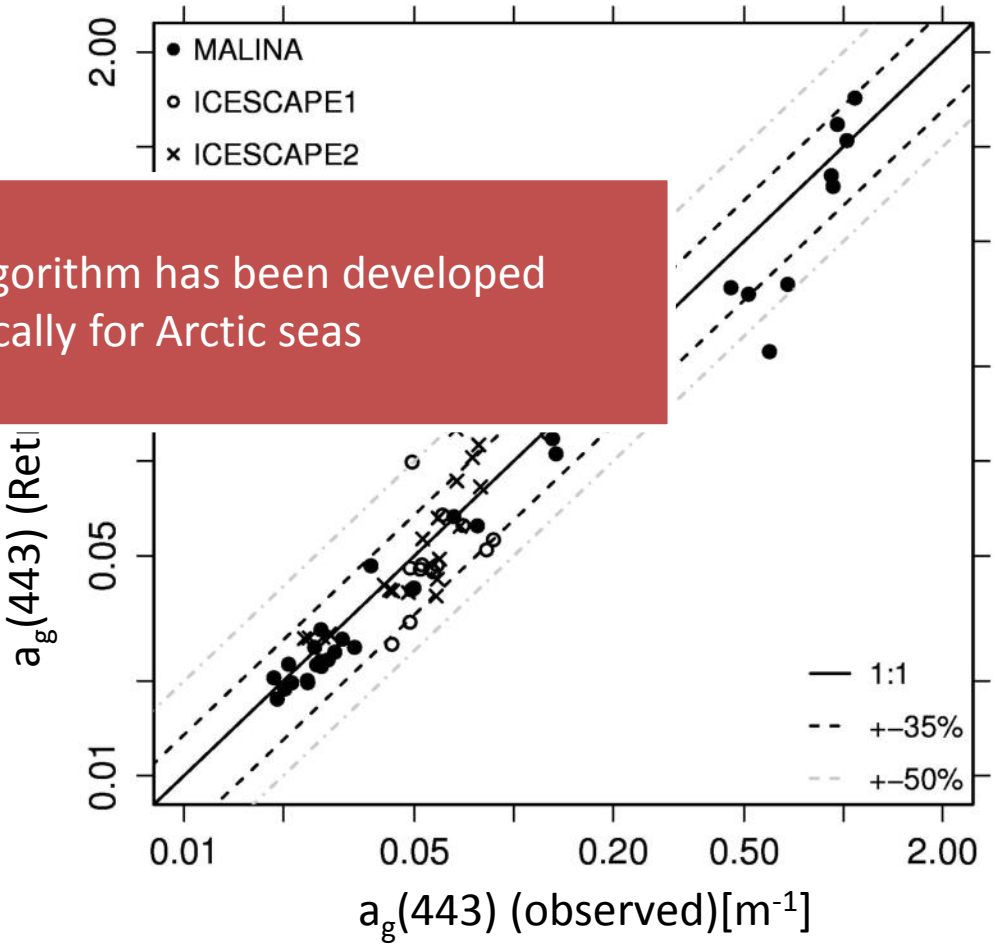
Matsuoka et al., 2013a, b

A new CDOM algorithm has been developed specifically for Arctic seas

Comparison of CDOM absorption estimates with *in situ* measurements

Datasets	r^2	Intercept	Slope	RMSE	MNB	*N*
This study	0.87	-0.022	0.97	0.069	8.58	79

➢ **This evaluation was made using independent datasets which were not used for developing this algorithm**



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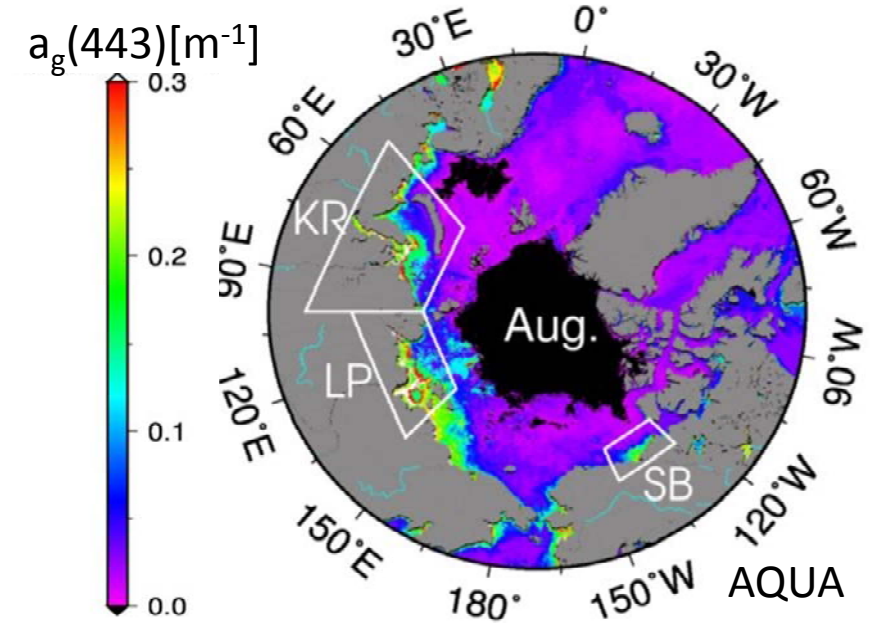
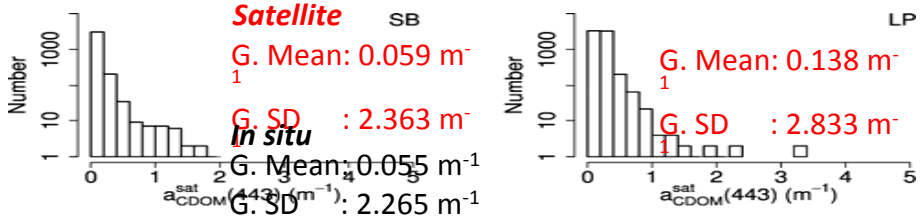
4.1 CDOM algorithmS

Climatology of $a_g(443)$ estimates for Arctic waters from space





Satellite

G. Mean: 0.059 m^{-1}

G. SD : 2.363 m^{-1}

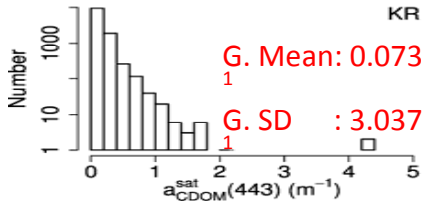
In situ

G. Mean: 0.055 m^{-1}

G. SD : 2.265 m^{-1}

G. Mean: 0.138 m^{-1}

G. SD : 2.833 m^{-1}

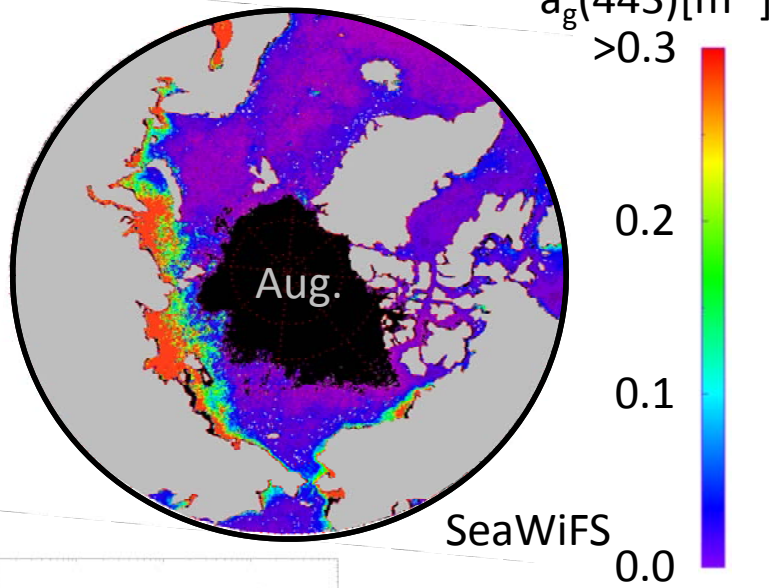


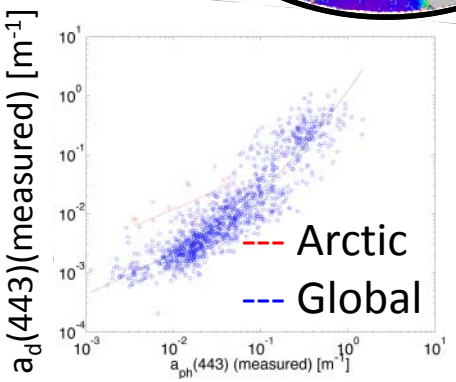
G. Mean: 0.073 m^{-1}

G. SD : 3.037 m^{-1}

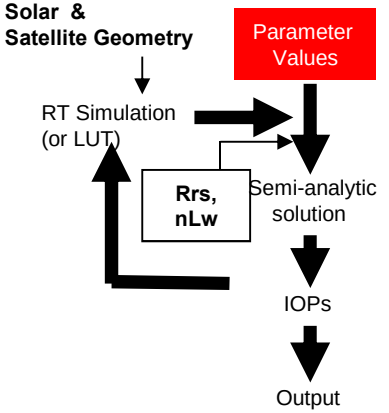
Matsuoka et al., 2013b

Modified IOP algor. (Assumed b_b spectra is not smooth any more)





$a_{ph}(443)$(measured) $[m^{-1}]$



$ag(443)=adg(443)-ad(443)$

$\log10[ad(443)]=0.407*\exp(0.328*\log10[a_{ph}(443)+2.22]-0.88$

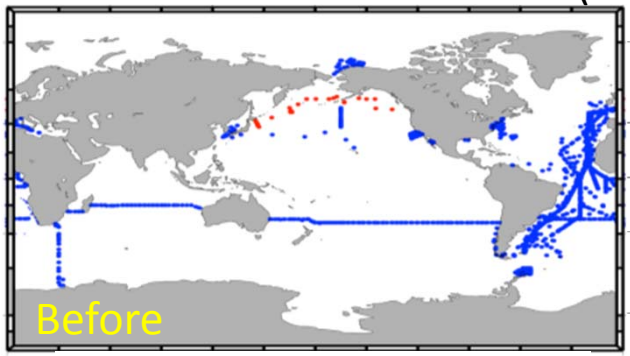
4.1 PFT algorithm

Rrs → $a_{ph}(\lambda=443)$ → Chla → PFTs (OC-PFT ver.1)
Rrs → → Chla → PFTs (OC-PFT ver.0)

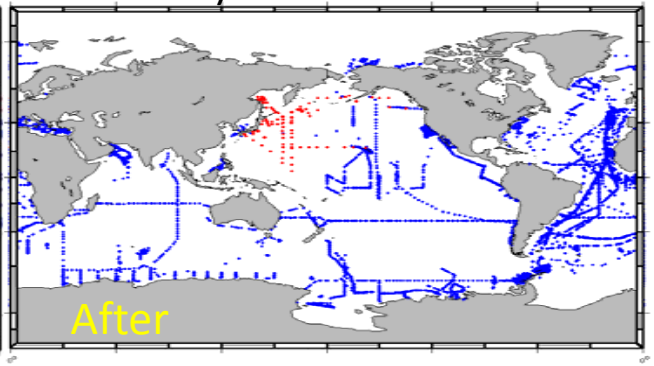
Held a session at IOCS, May 2013, Germany

Satellite PFT algorithm intercomparison project

http://pft.ees.hokudai.ac.jp/satellite/index.shtml



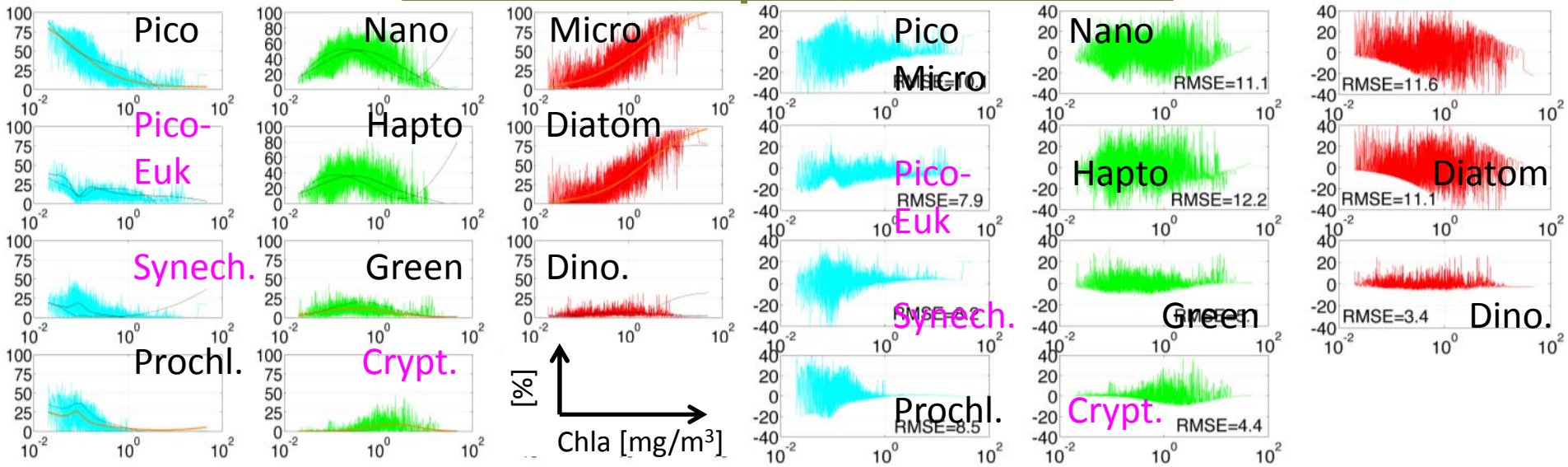
Data used in Hirata et al. (2011)
+
Data from GCOM-C Suzuki Team
(N=5870)



New Dataset Compiled this year
+
Data from GCOM-C Suzuki Team
(N=13503)

Soppa et al., in prep.

9 Phytoplankton groups have been increased to 11



After(before)	Pico	Nano	Micro	Green	Diatom	Prochl.	Synech.	Hapto	Dino.	Crypt.
RMSE	10.1(6.1)	11.1(7.6)	11.6(6.7)	5.1(4.2)	11.1(6.3)	8.5(6.1)	8.2(-)	12.2(8.4)	3.4(2.1)	4.4(-)

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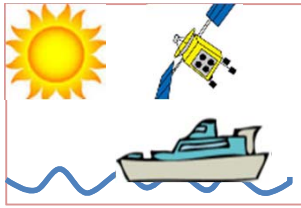
4.1 PFT algorithm

Algorithm testing

Steps towards validation:

STEP 1 Testing a biological part of the algorithm using in situ input

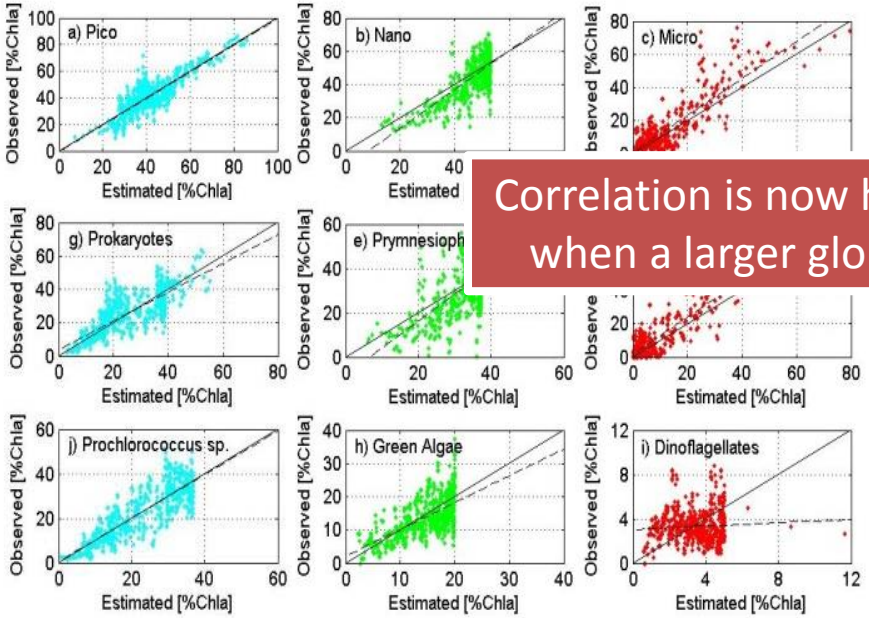
STEP 2 Validation of output products by using satellite input



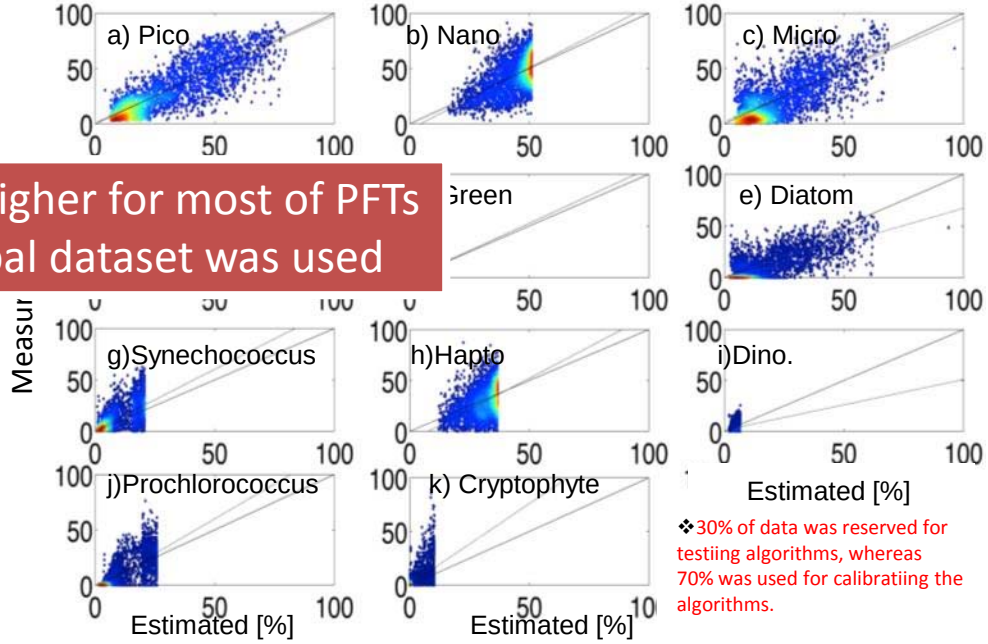
Input（satellite signal） → (algorithm) → satellite product（check outputs as a satellite product）

Input（in situ signal） → (algorithm)　（check bio-optical algorithm ）

Before



After



Correlation is now higher for most of PFTs when a larger global dataset was used

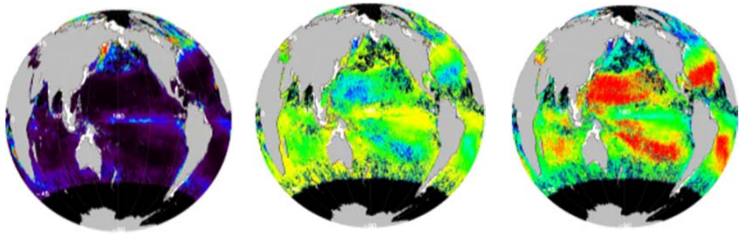
❖30% of data was reserved for testiing algorithms, whereas 70% was used for calibratiing the algorithms.

After (before)	Pico	Nano	Micro	Green	Diatom	Prochl.	Synech.	Hapto.	Dino.	Crypt.	Pico-Euk
r	0.88(0.74)	0.63(0.56)	0.79(0.72)	0.37(0.40)	0.79(0.73)	0.80(0.72)	0.69(-)	0.53(037)	0.29(0.00)	0.63(-)	0.60(-)
p	<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (0.001)	<0.001 (<0.001)	<0.001 (0.001)	<0.001 (<0.001)	<0.001(-)	<0.001 (0.001)	<0.001 (0106)	<0.001 (<0.001)	<0.001 (-)

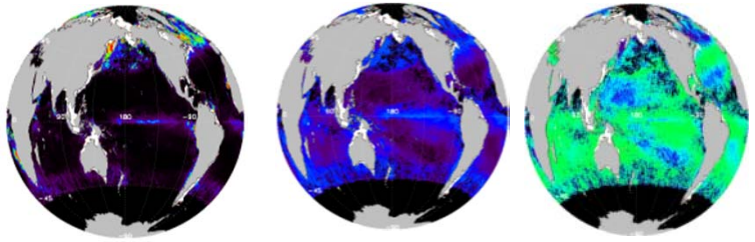
4.1 PFT algorithm

BEFORE(~2012)

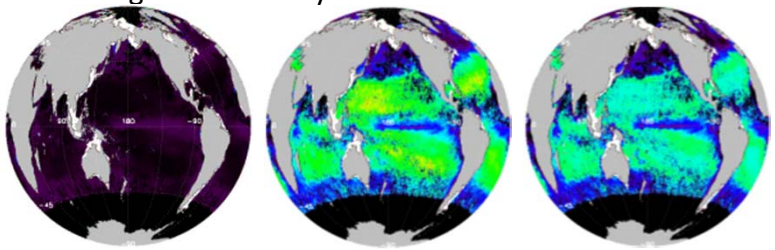
Micro | Nano | Pico



Diatom | Green Algae | Haptophyte

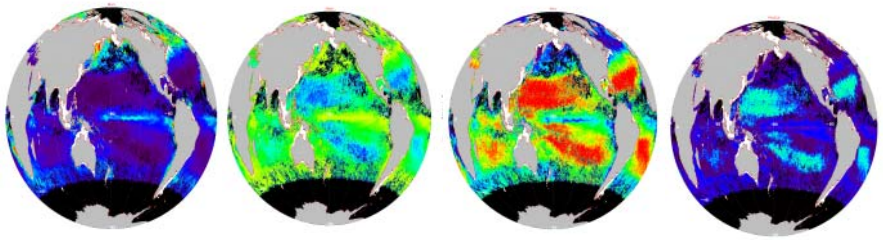


Dinoflagellate | cyanobacteria | Prochlorococcus

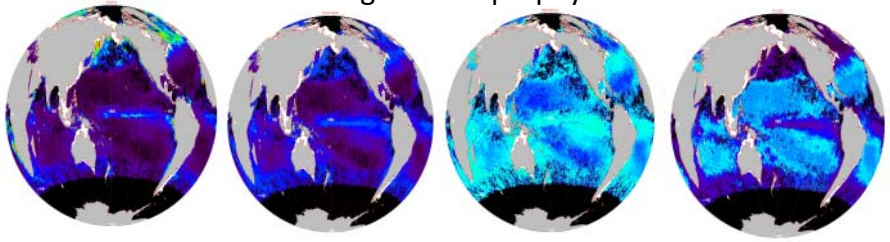


AFTER(2013)

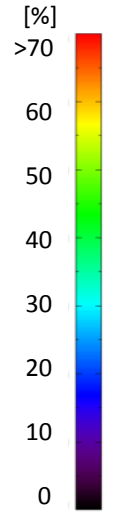
Micro | Nano | Pico | Pico-Eukaryotes



Diatom | GreenAlga | Haptophyte | Prochlorococcus



Dinoflagellate | Cryptophyte | Synechococcus



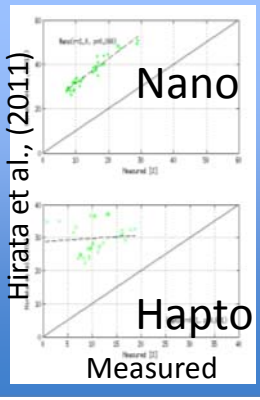
1. Cryptophyte
2. Synechococcous
3. Pico-Eukaryotes
   are added.

According to new parameterizations using the larger global in situ data,

- Nano was reduced by 8% from previous estimates
- Microplankton & Diatom have increased by about 6% from previous estimates
- Haptophyte was reduced by approx. 10%
- Prochlorococcus was reduced by 5%

An independent test of the previous algorithm (right) has been showing an overestimation of Nano & Hapto for

The North Pacific



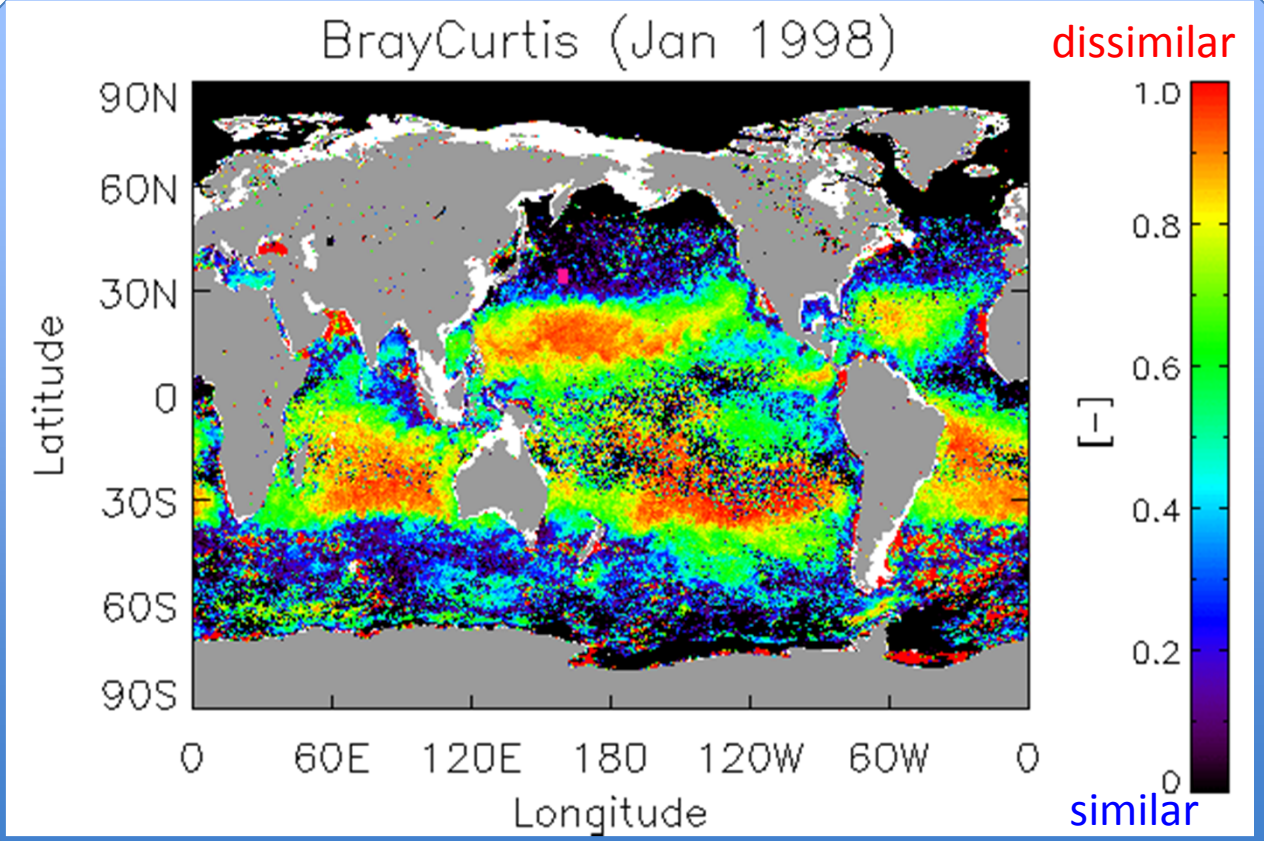
4.1 PFT algorithm

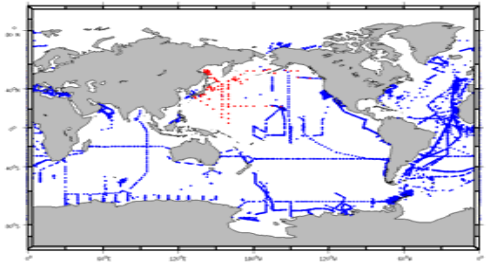
Classification of oceans for regional parameterization of PFT algorithms

$$\delta = \frac{\sum_{i=1}^{S} \left| n_{i,a} - n_{i,b} \right|}{N_a + N_b}$$

i: index for a certain PFT
S: Number of PFT in consideration (size classification removed here))
b: Base grid (location)
$n_{i,a}$, $n_{i,b}$: Pigment biomass of each PFT at the base grid and other grids
N_a, N_b: Total pigment biomass at base and other grids.

Relative difference in community structure. Parameterizations for different oceanic regions?





Regional parameterization is on going

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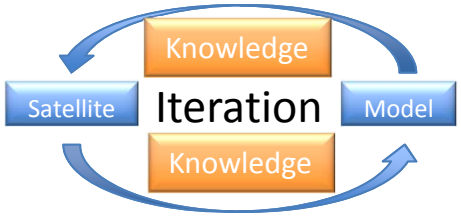
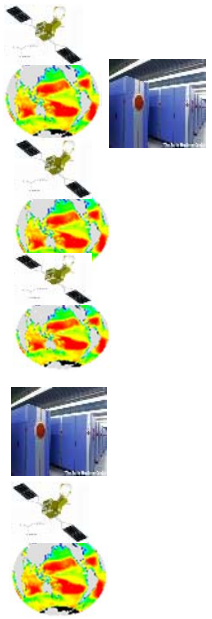


4.3 Model & Satellite Analysis

GCOM Global Change Observation Mission



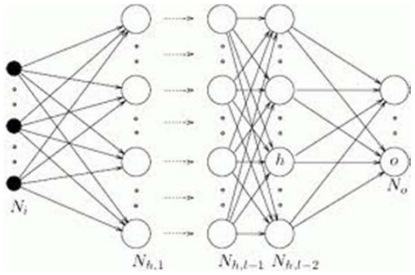
SST

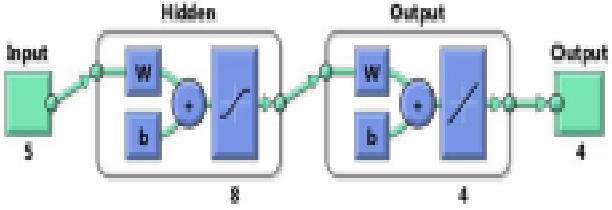
PAR

SSW

MLD

Chla





Diatom

Cocolithophore

Cyanobacteria

Chlrorophyte

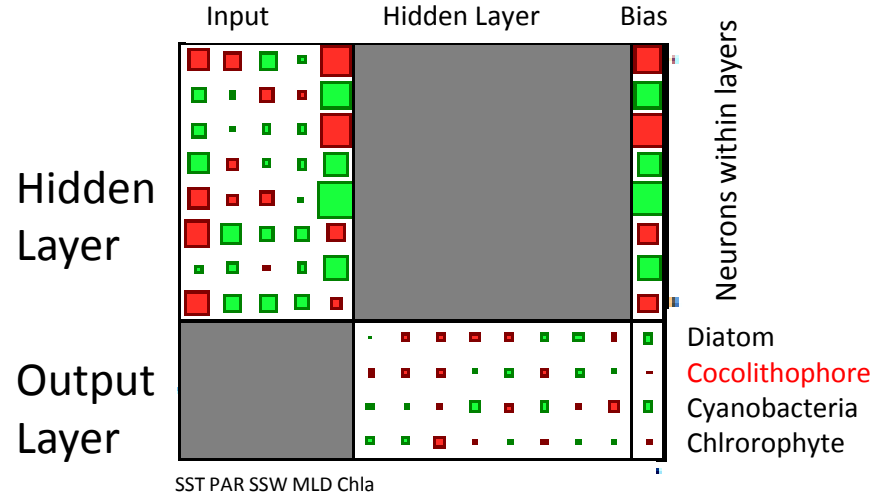
Hinton-weight diagram

Correlation with weight

Positive

Negative

Size indicates Strength of correlation



Palacz et al., 2013

Model Used For Training : NASA Ocean Biogeochemistry Model (NOMB)

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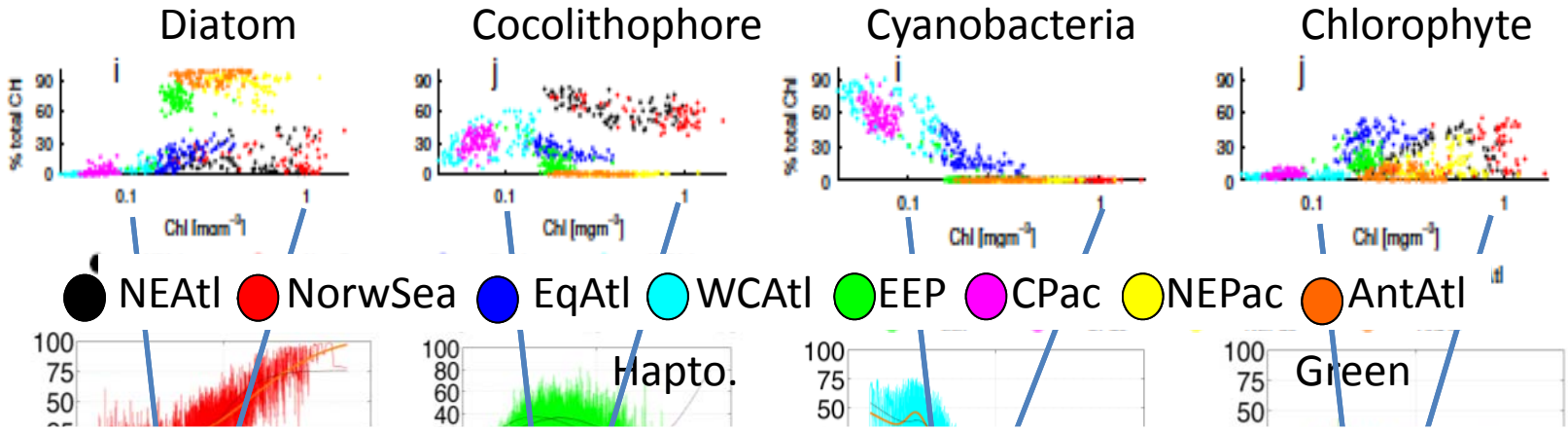
4.3 Model-Satellite Integrated analysis

GCOM Global Change Observation Mission

[%]

Chla [mg/m^3]

Palacz et al., 2013



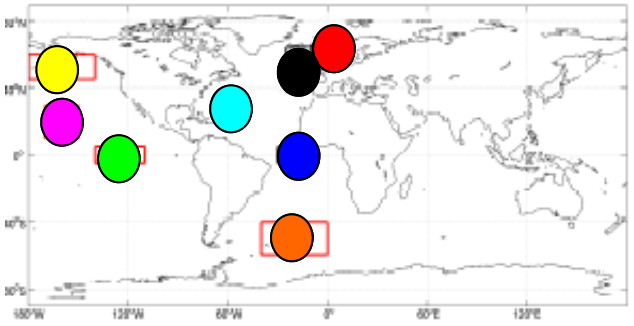
We identified:

Potential weakness of our PFT algorithms for certain PFTs and oceanic regions

Area
disag

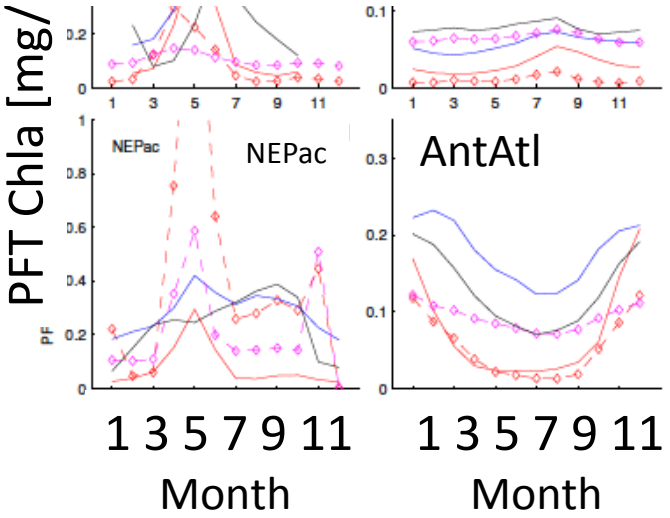
NEPac

Areas disagreed depend on PFTs in consideration



Disagreement in Chla biomass of diatom (Also bloom timing for NorwSea)

Bias in Chla biomass of coco(hapto)



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Summary

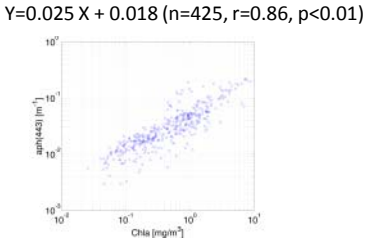
- We got another CDOM algorithm for Arctic seas
- A large in situ dataset has been complied under participation in an international project (+ another dataset from GCOM-C Suzuki Team)
- PFT algorithms were re-calibrated with a larger global dataset
- Model analysis identified potential weakness of the PFT algorithms for some oceanic regions and PFTs, and gave “hints” for further improvement of the algorithms.

Plans for the next year(FY 2014)

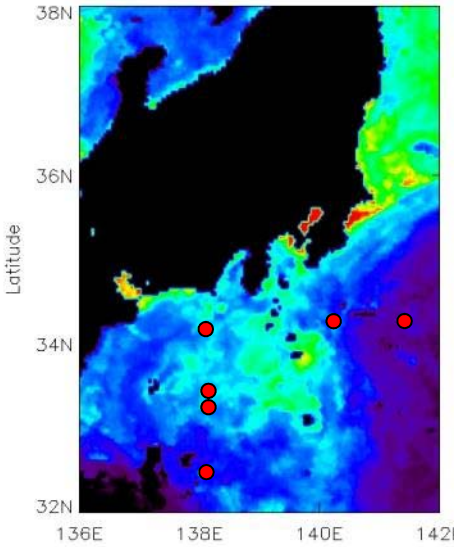
- Comparison of CDOM algorithms for Arctic seas
- Development of “correction scheme” for regional improvement of PFT algorithms
- Calibration of Ver.1 of PFT algorithms (i.e. Rrs→a_{ph}(443)→Chla→PFTs) rather than Ver.0 (i.e. Rrs→Chla→PFTs)
- Compilation of CDOM measurement protocol for algorithm validation (in collaboration with GCOM-C Hirawake Team)

4.1 PFT algorithm

Rrs → $a_{ph}(\lambda=443)$ → Chla → PFTs (OC-PFT ver.1)
→ Chla → PFTs (OC-PFT ver.0)

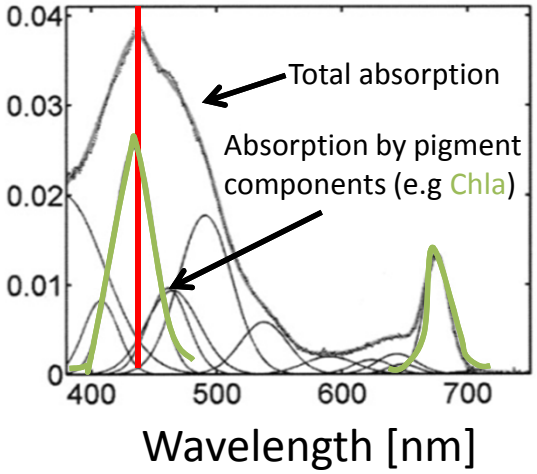


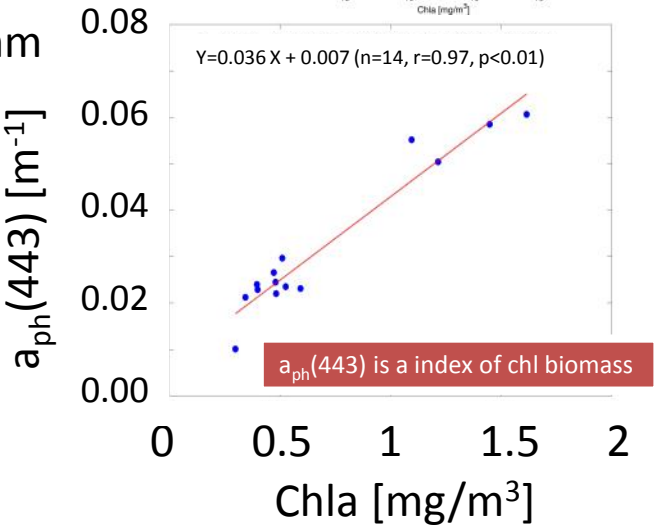
Field observation SY13−04 April 2013

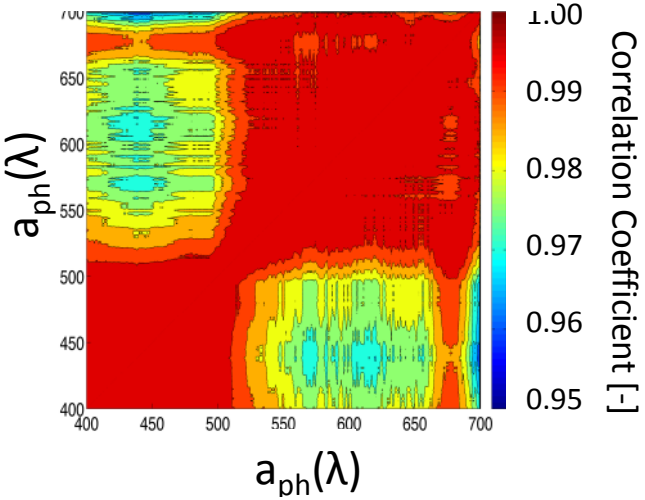


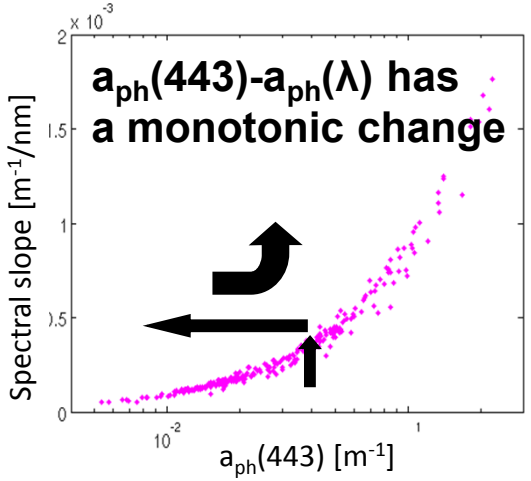
Data from SY13-04 cruise this year

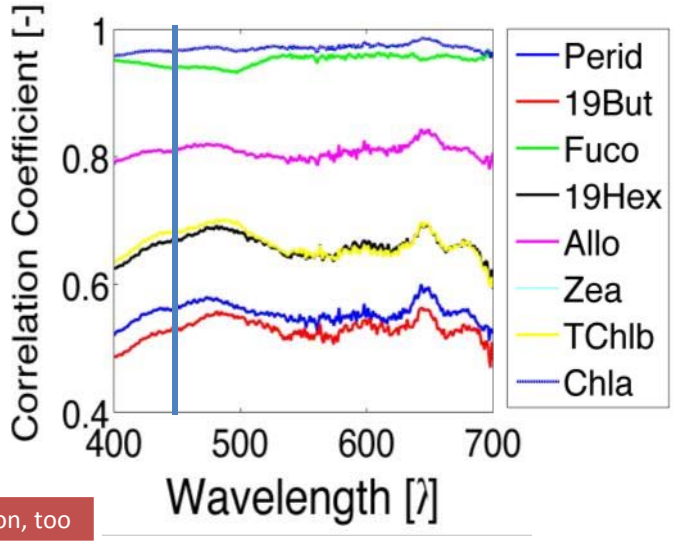
chlorophyll-a peak is found at 443nm











aph(443) is implicitly an index of pigment composition, too