Ocean Color Time Series

(and merged data sets)
(and examples of what to do with them)

NASA REASoN

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UCSB

Current situation

- Several simultaneous global ocean color missions
- Several versions of the same product

Benefits of Data Merging:

- Development of unified, consistent ocean color time-series from multiple sensors (ESDRs, CDRs)
- Improved spatial and temporal coverage
- More diverse ocean color products with lower uncertainties

Difficulties:

- Sensors are not created equal: different designs, calibrations, algorithms, accuracies,….
- Large volumes of data to deal with
- Merging procedure should not create biases, discontinuities, artifacts,…

NASA Research, Education, and Applications Solution Network (REASoN)

Ocean Color Time-series Project

UCSB component:

1) develop merged data sets from SeaWiFS, Aqua, Terra data: Chl and other products

2) distribute the merged products

3) do science with the merged products

THE GSM01 MERGING MODEL

(Garver & Siegel, 1997; Maritorena et al., 2002; Maritorena & Siegel, 2005).

$$L_{wN}(\lambda) = \frac{t\,F_0(\lambda)}{n_w^2} \sum_{i=1}^{2} g_i \left(\frac{b_{bw}(\lambda) + b_{bp}(\lambda)}{b_{bw}(\lambda) + b_{bp}(\lambda) + a_w(\lambda) + a_{ph}(\lambda) + a_{cdm}(\lambda)} \right)^i$$

Non-water components of absorption and scattering are expressed as known shape functions with an unknown magnitudes:

- $a_{ph}(\lambda) = Chl\ a_{ph}^*(\lambda)$
- $a_{cdm}(\lambda) = a_{cdm}(443) \exp(-S(\lambda - 443))$
- $b_{bp}(\lambda) = b_{bp}(443)\ (\lambda / 443)^{-\eta}$

Fixed parameters were optimized for global applications using a large in situ data set

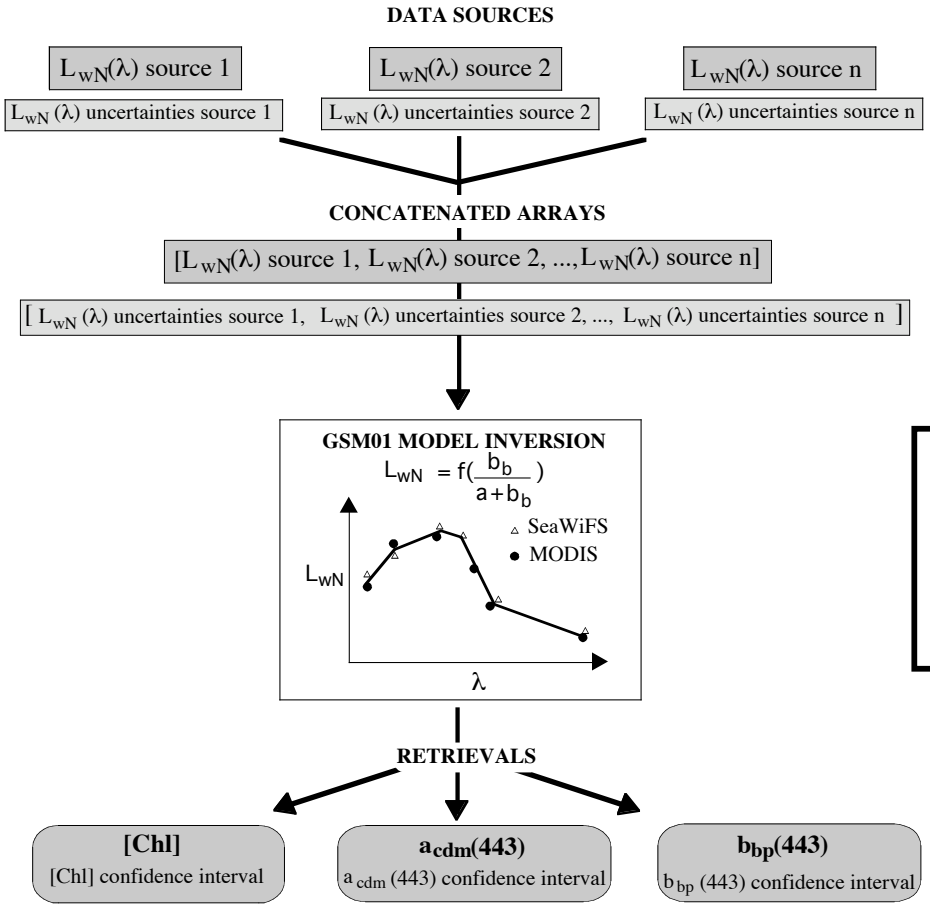
Non-linear least-square technique is used to solve for the unknowns (chl, $a_{cdm}(443)$ and $b_{bp}(443)$) from $L_{wN}(\lambda)$ data at 4 or more wavelengths.

Uncertainties of the input $L_{wN}(\lambda)$ can be taken into account.

Confidence intervals of the retrievals are estimated by linear approximation of non-linear inference regression

GSM01 is a Case I non-polar water model

Merging technique = GSM model

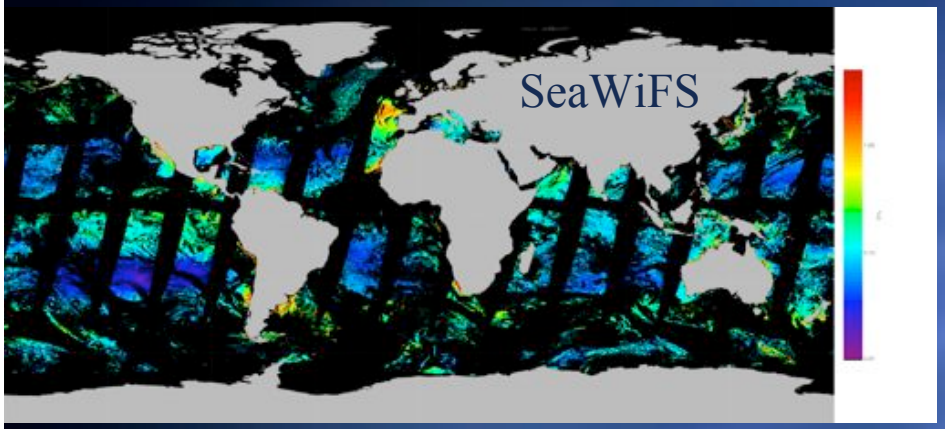


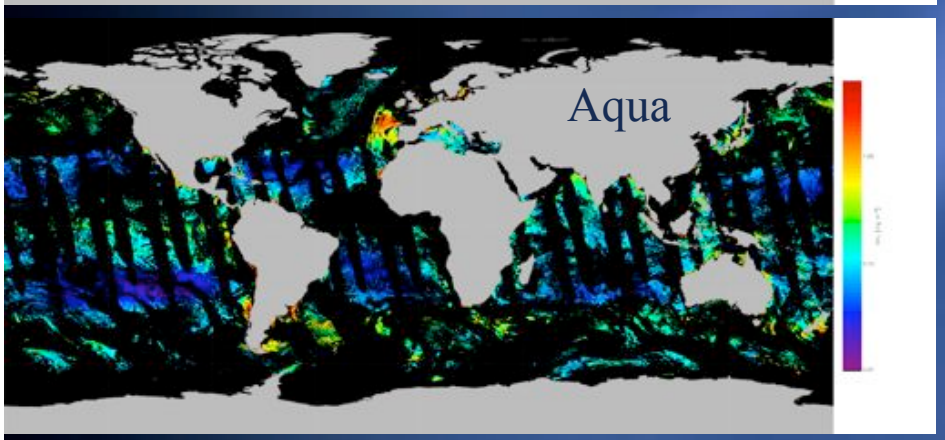
9 km grid
Level-3 data

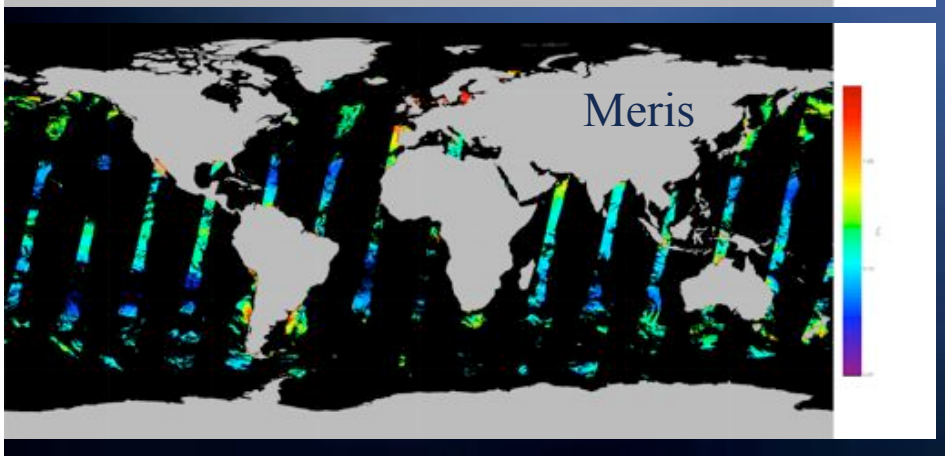
SeaWiFS	412	443	490	510			555	
Aqua	412	443	488		531	551		
Meris	412	443	490	510				560
Merged	412	443	490	510	531	551	555	560

Maritorena & Siegel, 2005

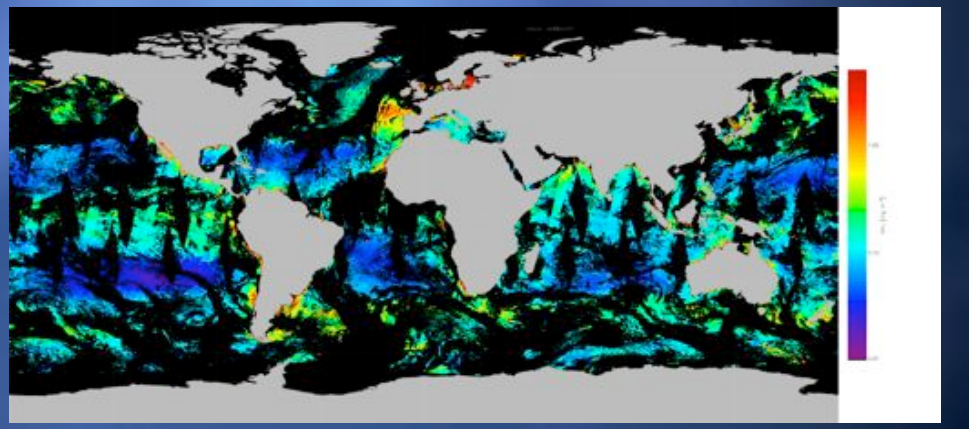
Daily 9 km data - March 21, 2003



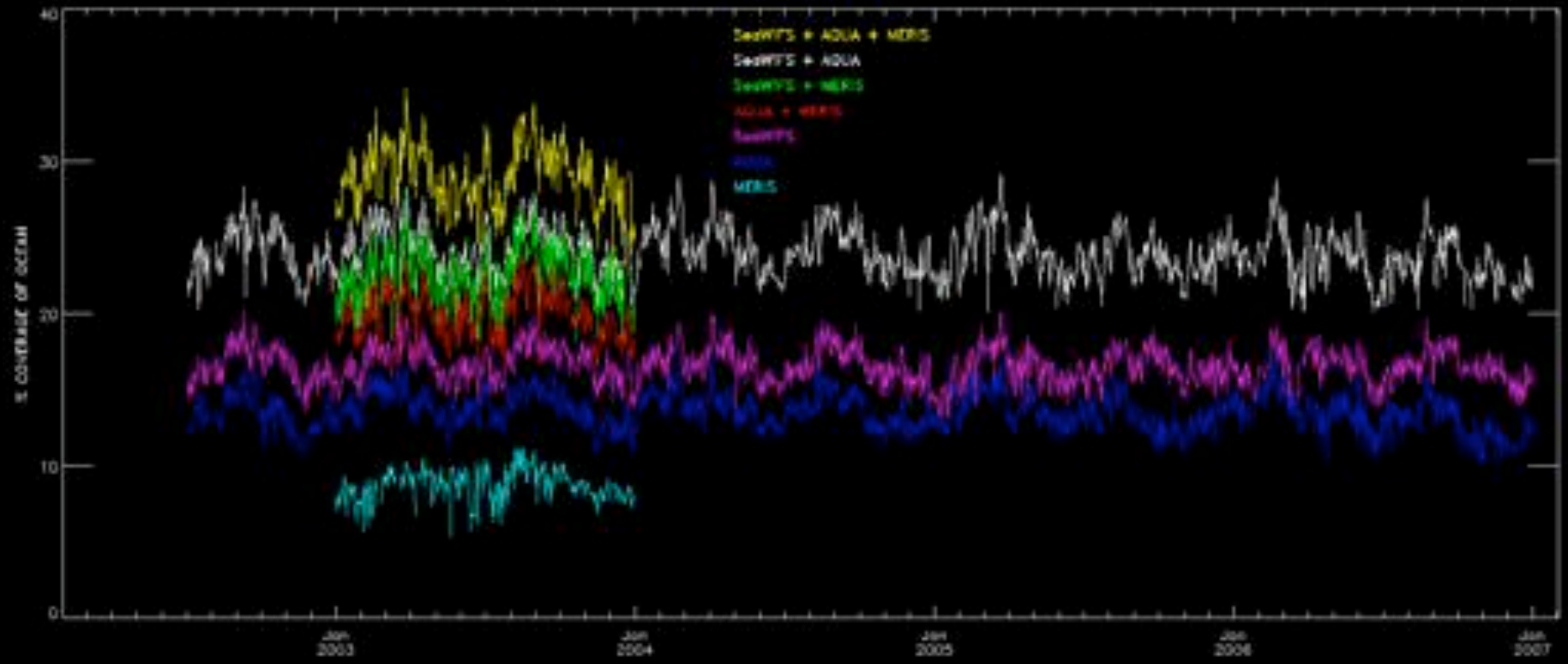




Merged



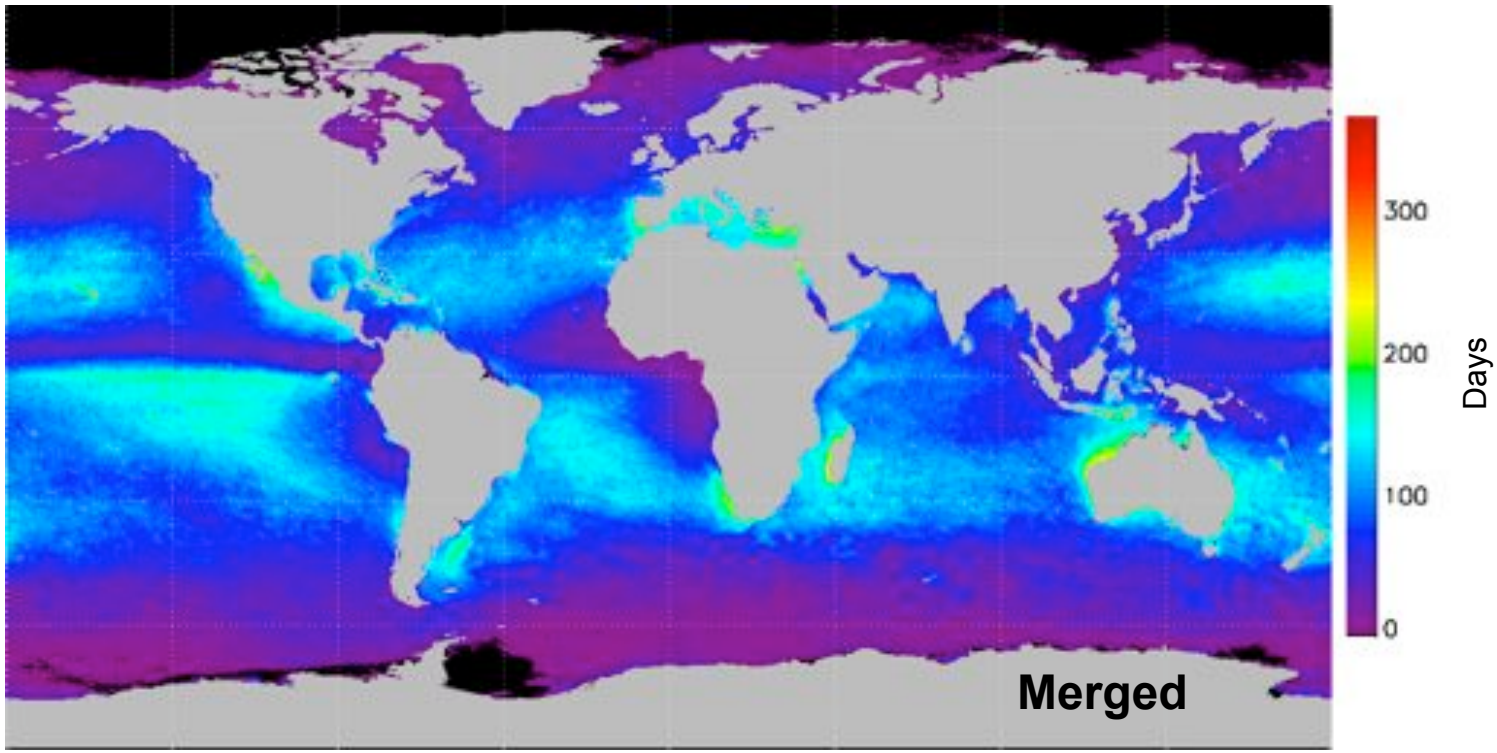
COVERAGE

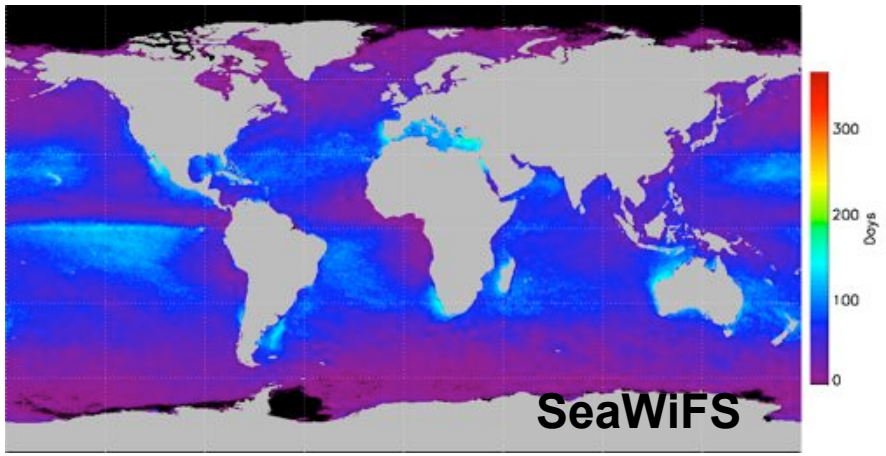

SeaWiFS + AQUA + MERIS
SeaWiFS + AQUA
SeaWiFS + MERIS
AQUA + MERIS
SeaWiFS
AQUA
MERIS
40
30
20
10
0
2003
2004
2005
2006
2007

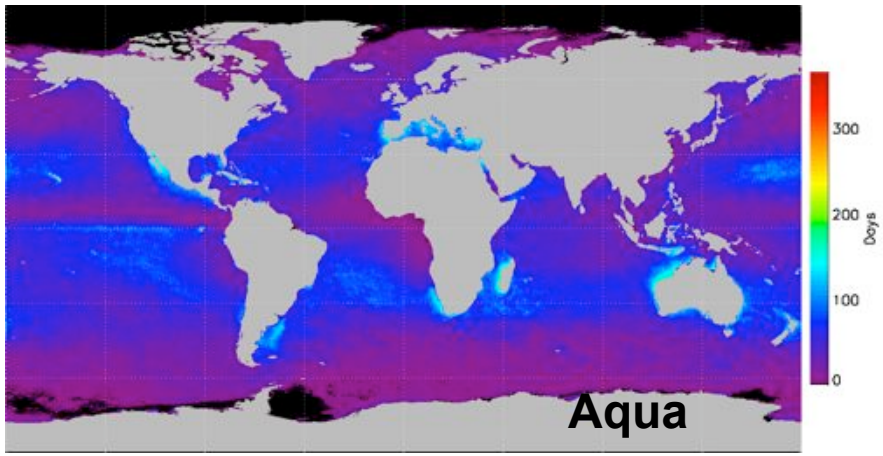
Ocean color sensors
average daily coverage (2003 data)

Sensor(s)	Coverage (%)	Std. Dev. (%)
SeaWiFS	16.65	2.01
Aqua	13.76	1.15
Meris	8.51	1.48
SeaWiFS/Aqua	24.22	1.94
SeaWiFS/Meris	22.24	2.40
Aqua/ Meris	19.92	1.74
SeaWiFS/Aqua/Meris	28.85	2.241

FREQUENCY OF COVERAGE (2005)

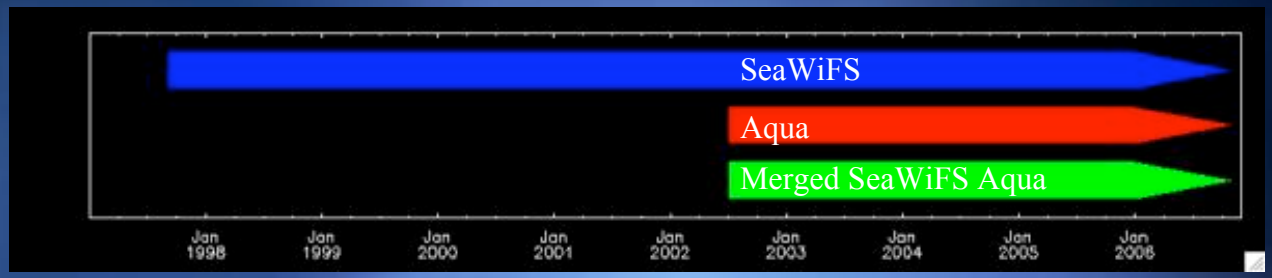






NASA REASoN GSM Merged data sets

- global 9 km
  - Daily
  - 4-Day
  - weekly (8D)
  - monthly



  - Chl (+ confidence intervals for dailies)
  - $a_{cdm}(443)$ (+ confidence intervals for dailies)
  - $b_{bp}(443)$ (+ confidence intervals for dailies)
  - coverage map

- Product files in HDF compressed format (4320 x 2160 arrays)

- Merged SeaWiFS-Aqua, SeaWiFS only, Aqua only.

- Available at:
  - ftp:ftp.oceancolor.ucsb.edu/pub/org/oceancolor/REASoN/
  - OPeNDAP server: http://dap.oceancolor.ucsb.edu/cgi-bin/nph-dods/data/oceancolor/
  - NASA GIOVANNI (Monthly)

REASoN Data - Reprocessings

REASoN data versions and features.

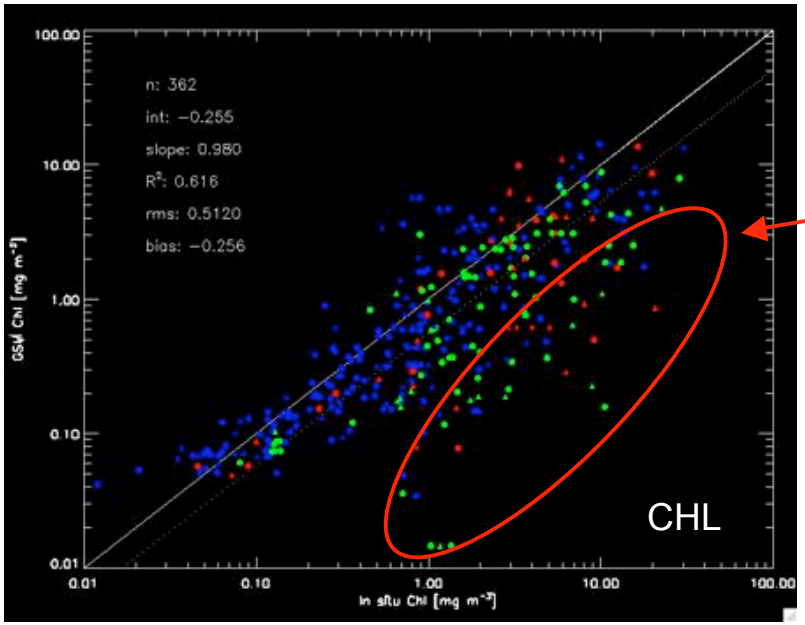
- v1 (completed Feb. 2005) : used mapped $L_{wn}(\lambda)$ data from MODIS-Aqua reprocessing 1 and SeaWiFS reprocessing 4.1

- v2 (completed Feb. 2006) : used mapped $L_{wn}(\lambda)$ data from MODIS-Aqua reprocessing 1.1 and SeaWiFS reprocessing 5.1. Fix a few bugs.

- Version with MERIS (completed Oct. 2006): merging with MERIS 2003 data. Used binned $L_{wn}(\lambda)$ data.

- v3 (completed Feb. 07): used binned $L_{wn}(\lambda)$ data. Improved 4.6 -> 9 km conversion for MODIS-Aqua, better stats and coverage. Files saved as mapped and binned.

MATCHUPS - NOMAD + SeaBASS 2003-2006 Data

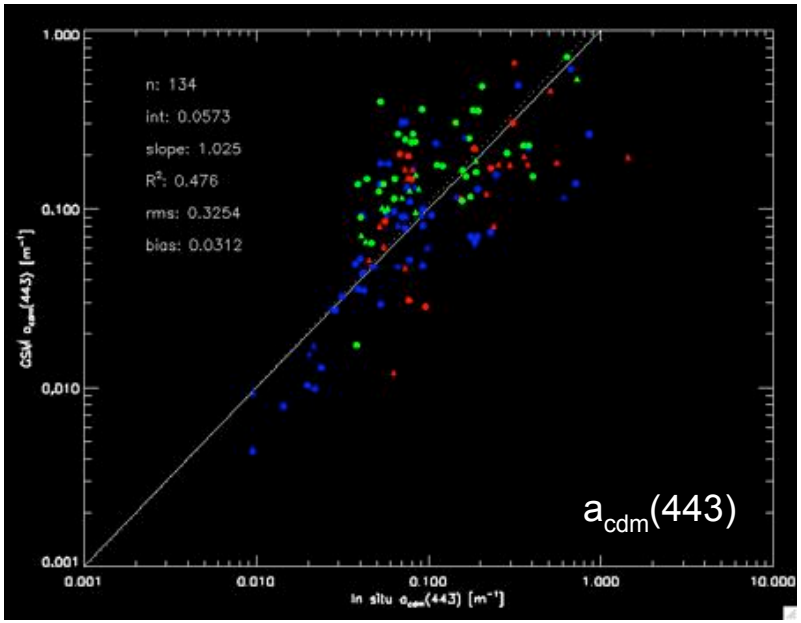


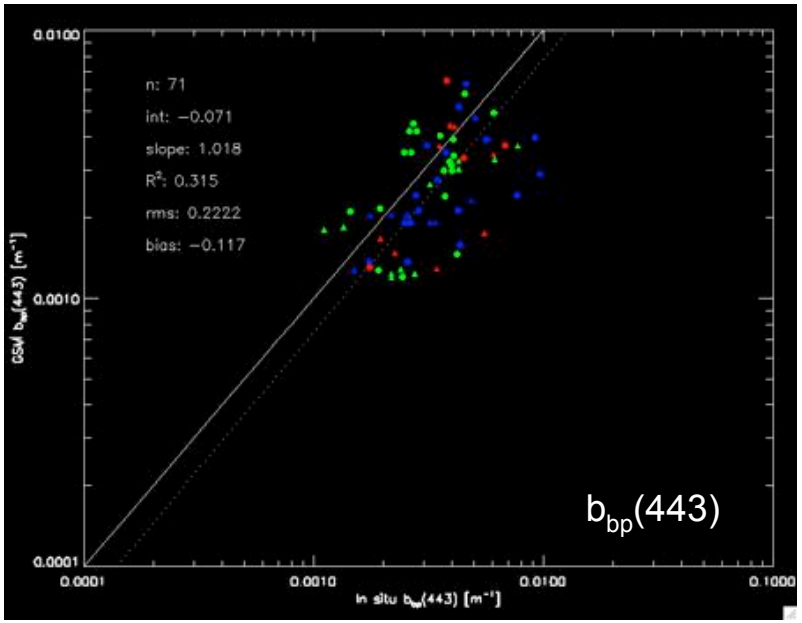
Plumes & Blooms
Martha Vineyard
Mississippi Δ
Scotia Prince Ferry
Chesapeake Bay
Antarctica

SeaWiFS

Aqua

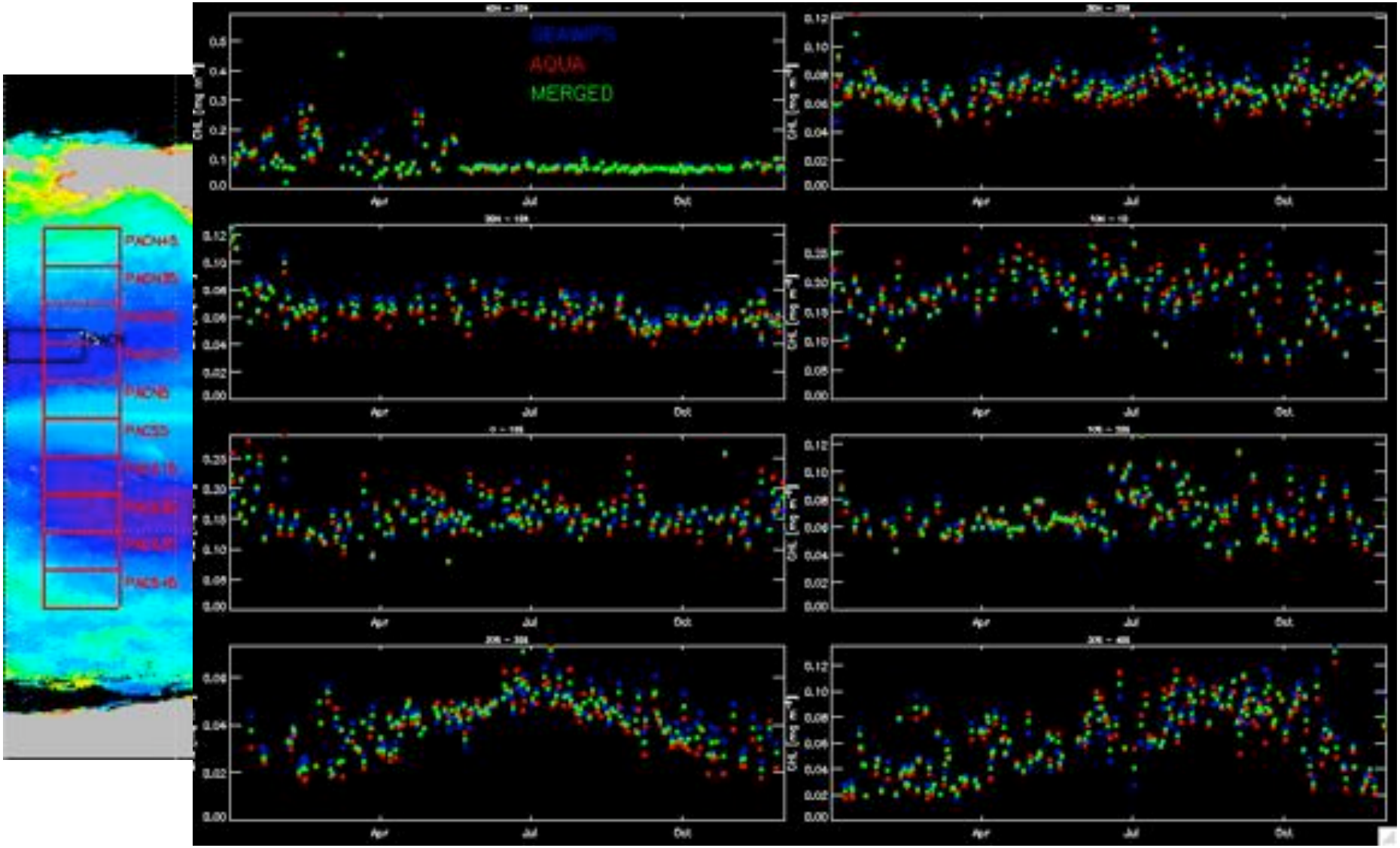
Merged



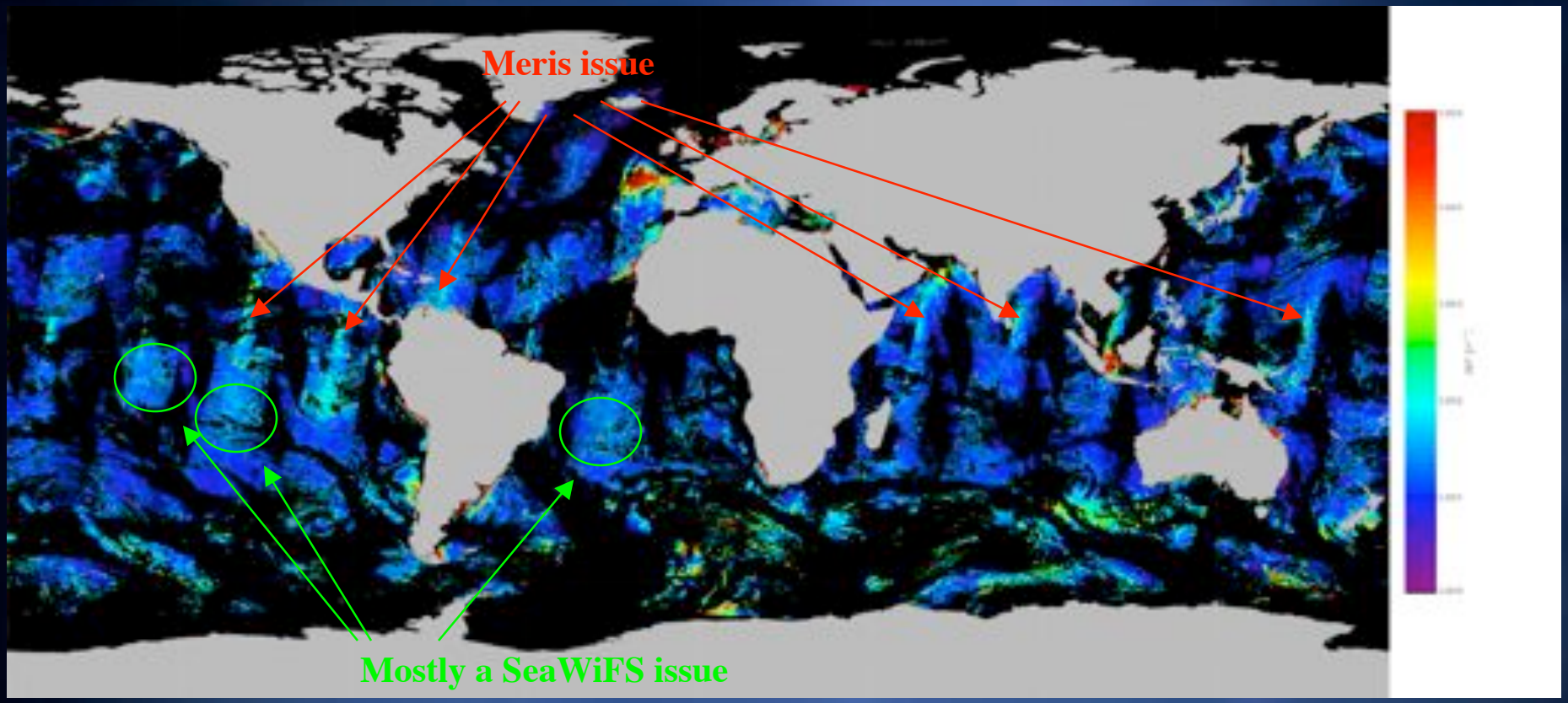


Chl - latitudinal comparison

SeaWiFS Aqua Merged



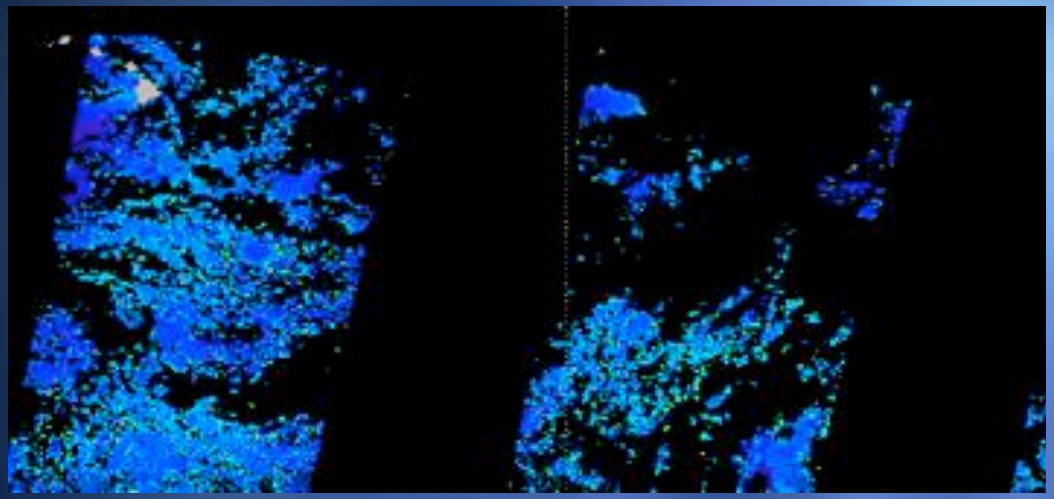
Issues with the particulate backscattering product



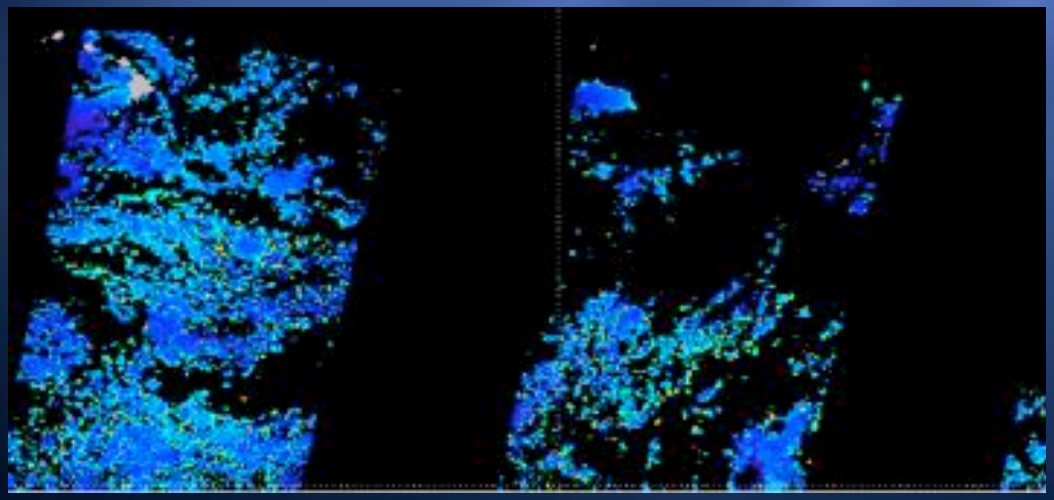
- Noise in the SeaWiFS and Meris Lwns around gaps caused by clouds. In these areas, the Lwn(λ) are sometimes higher than in nearby gap-free areas and this results in enhanced b_{bp} (443) values.
- Problem seems much less important in Aqua data
- This noise is not uniformly distributed but seems to mostly affect mid-latitudes in the southern hemisphere.
- Meris shows some high b_{bp} values on the western edge of some swaths.

Noise in the backscattering product with SeaWiFS

SeaWiFS $L_{wN}(555)$

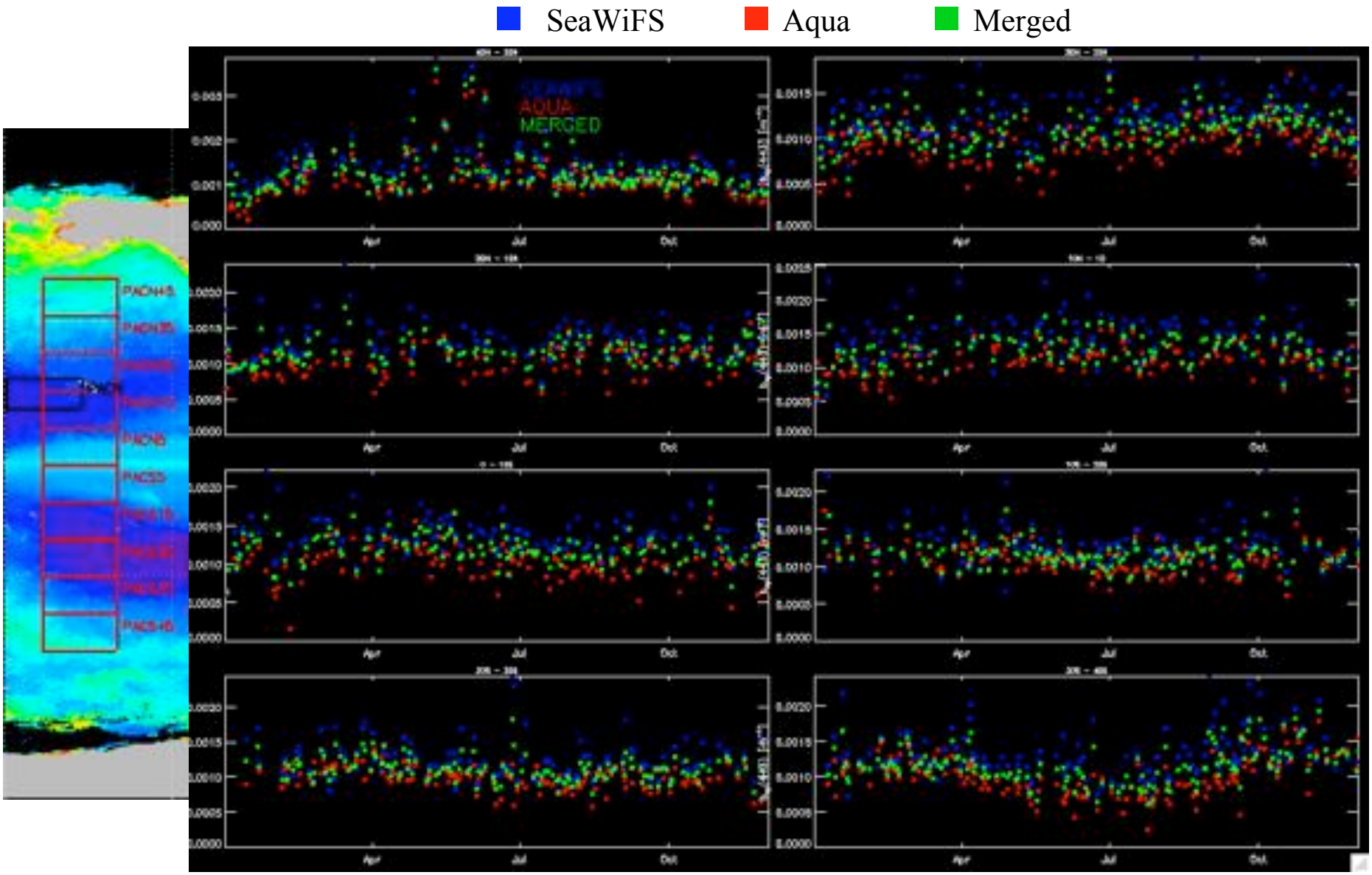


SeaWiFS $b_{bp}(443)$



- "Ringing" issue
- High $L_{wN}(\lambda)$ values around cloud gaps
- Can be filtered but will result in loss of coverage
- Does not happen with Aqua data

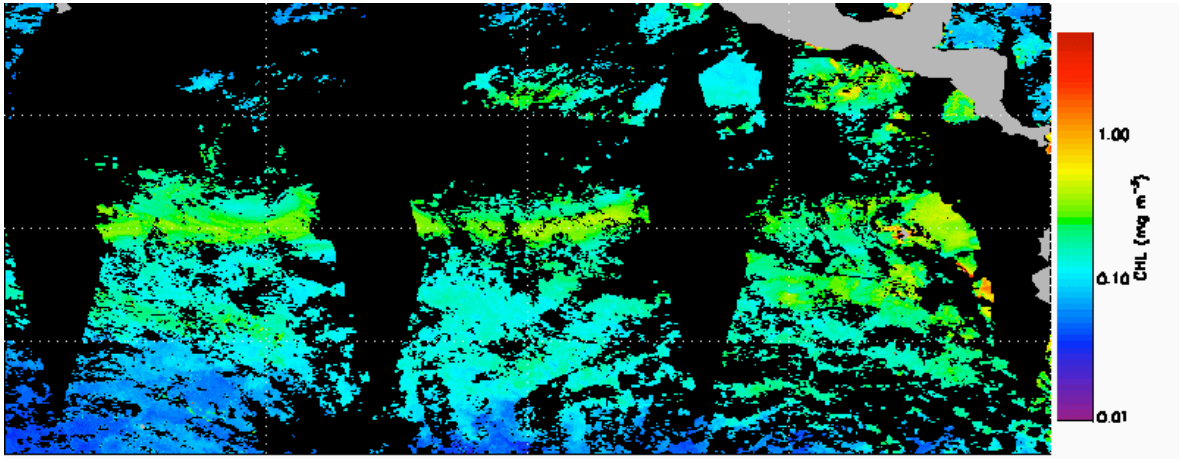
$b_{bp}(443)$ - latitudinal comparison



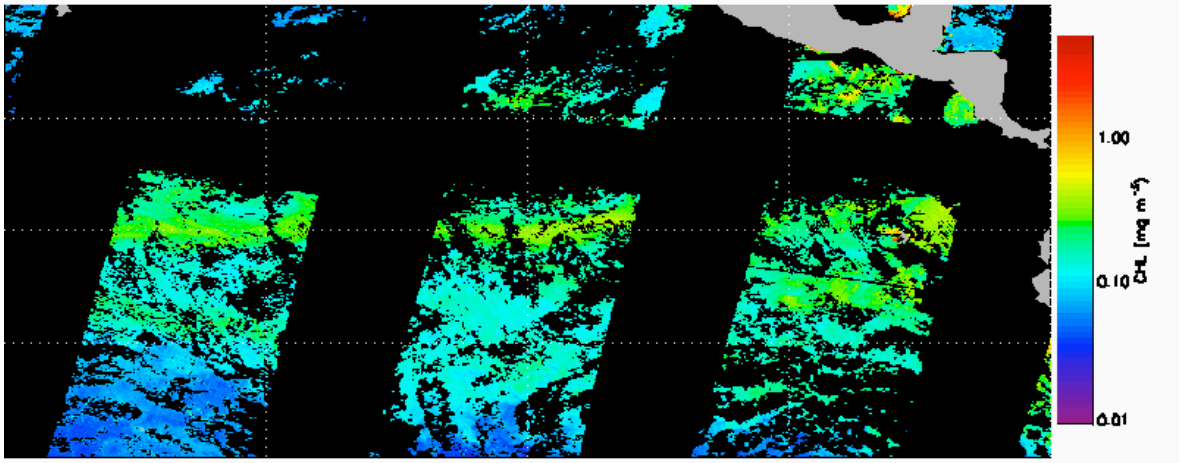
What to do with the merged data sets ?

What we are currently doing at UCSB:

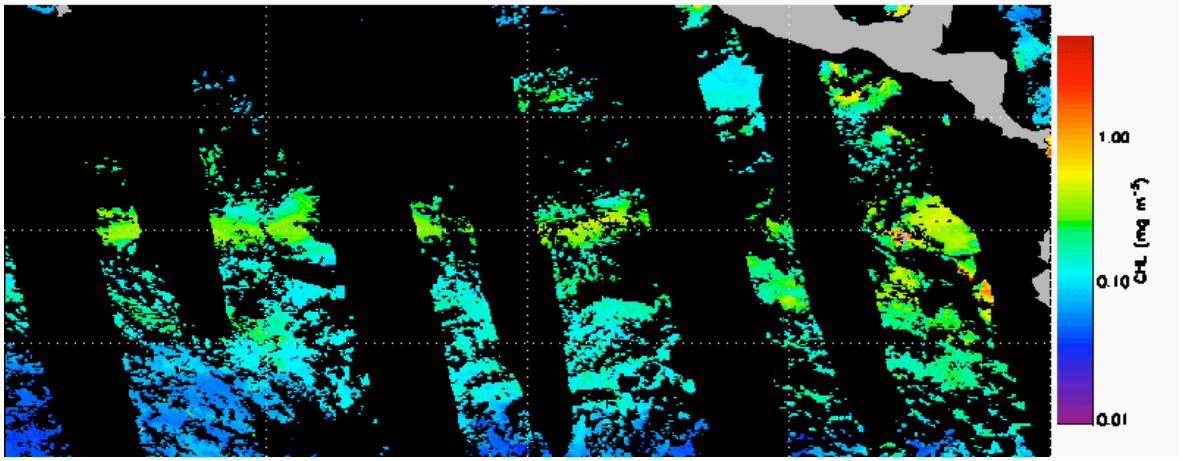
- Eddies and open ocean biogeochemistry in the Sargasso Sea
- Export particle source regions and the horizontal advection of sinking particles
- Spring blooms
- CDOM in the Southern Ocean
- Spatial structure/decorrelation scales



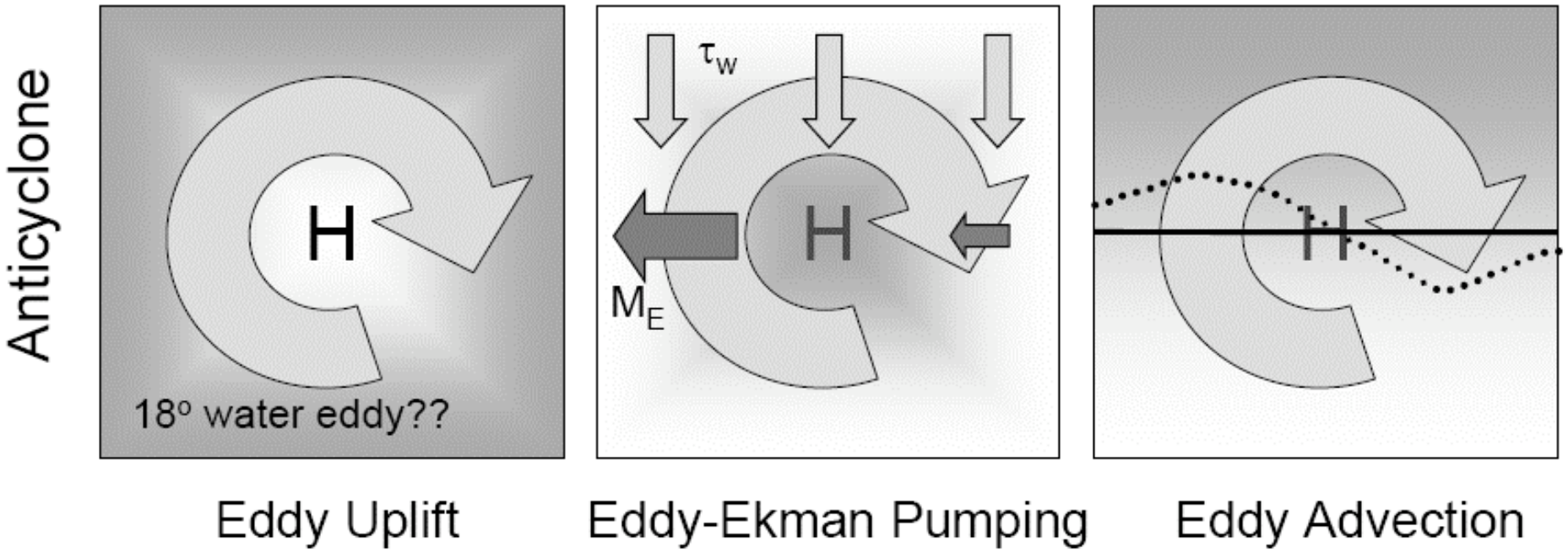
GSM CHL 2003109



GSM CHL 2003109

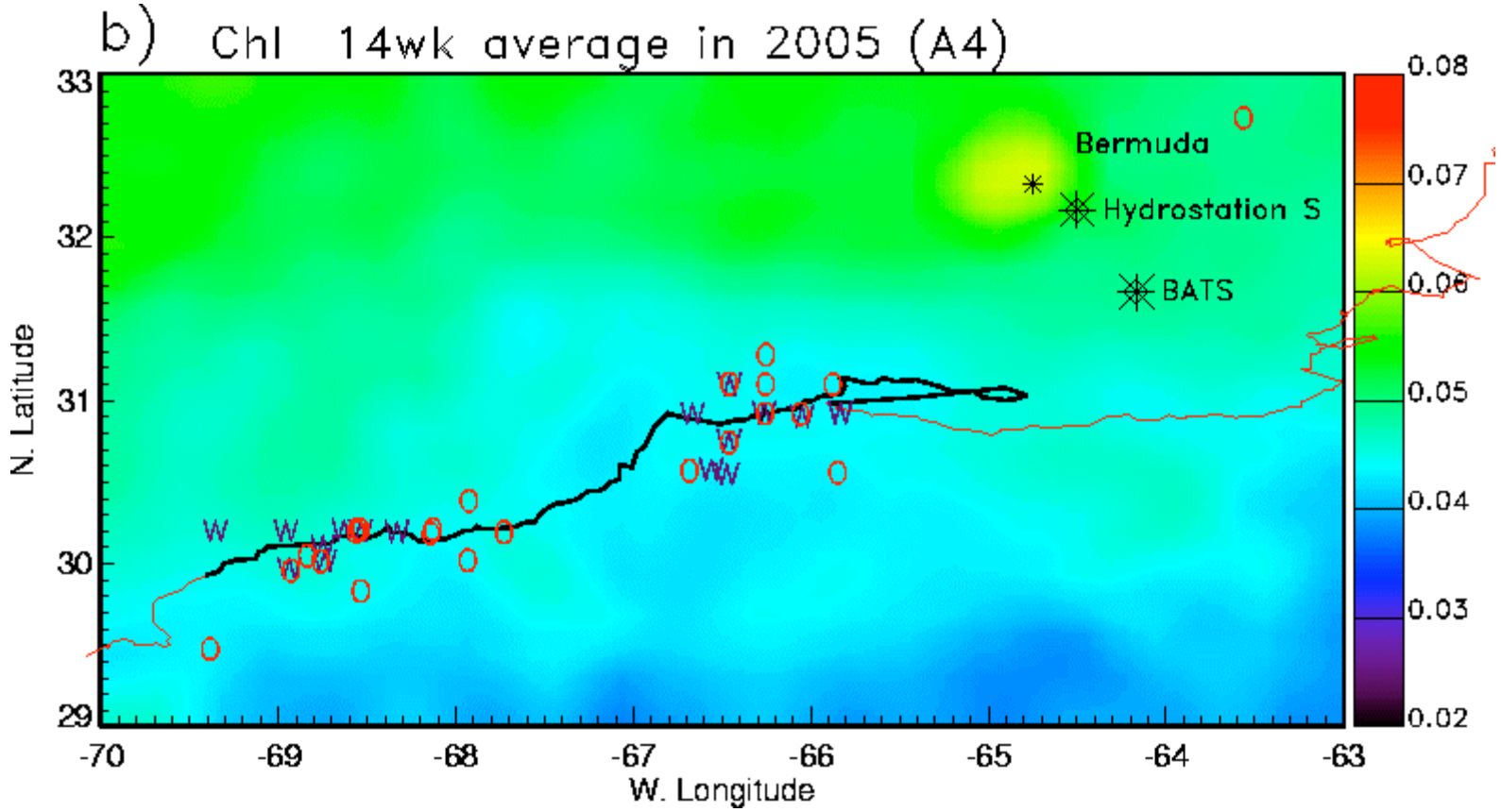


Hypothesized Mechanisms for Eddy Influences on Ocean Color Imagery



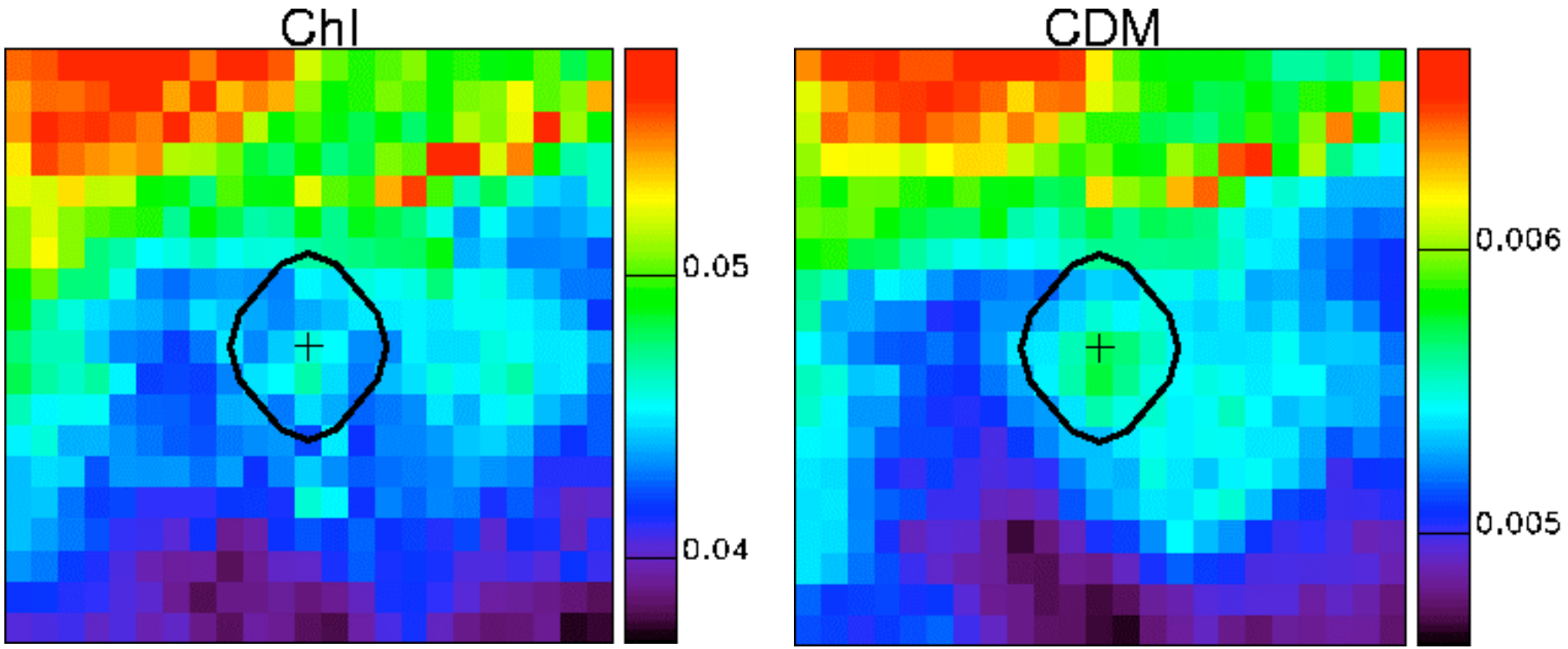
Siegel et al. [in review]

Path of Anticyclone A4 Sampled During EDDIES 2005



Description of EDDIES - McGillicuddy et al. [in press] *Science*

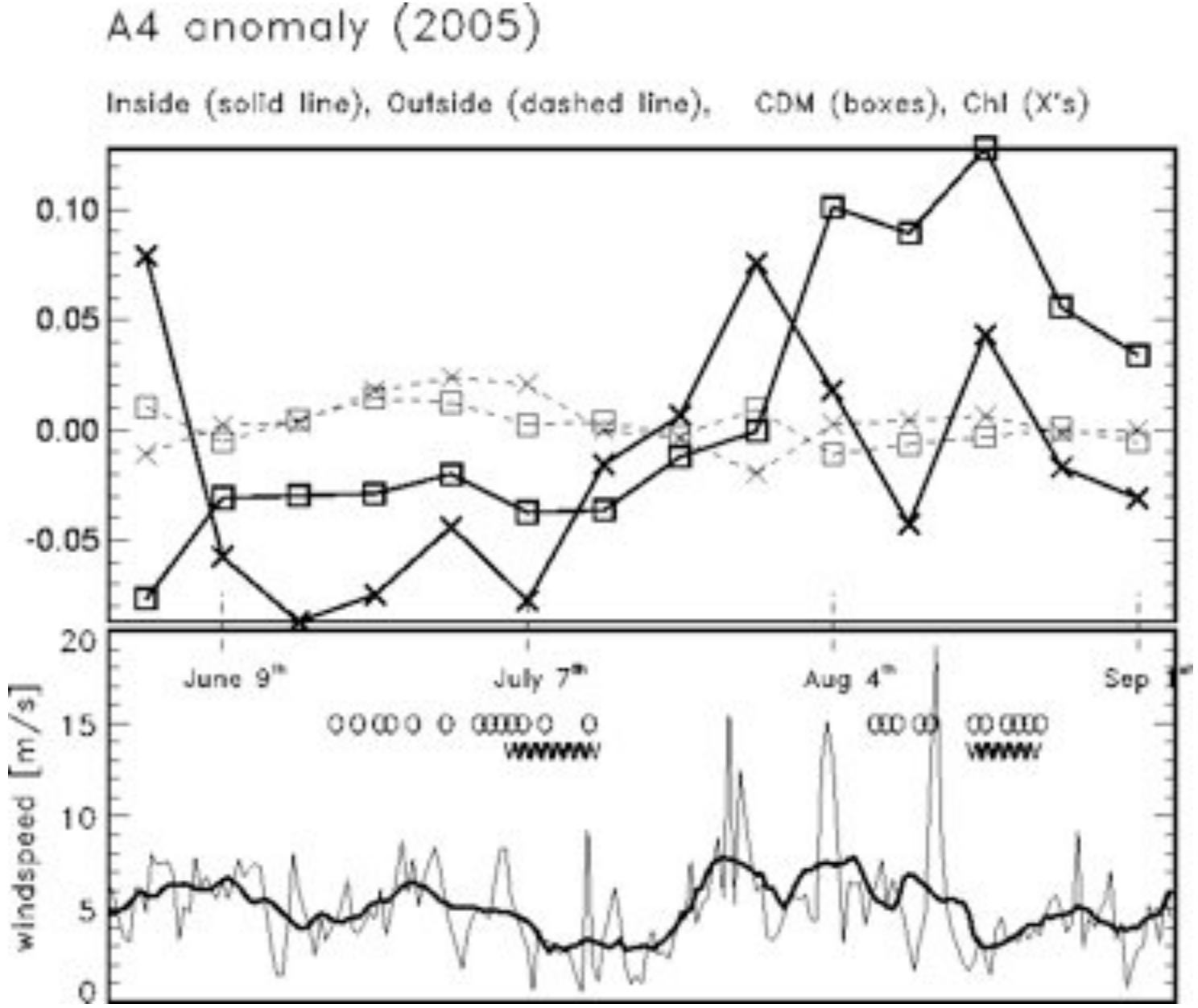
Eddy Centric Maps of Chl & CDM Following Anticyclone A4



Eddy interior is not significantly different than exterior

Signals are higher east & lower west of eddy -> eddy advection!

500 km averages following anticyclone A4


A4 anomaly (2005)
Inside (solid line), Outside (dashed line), CDM (boxes), Chl (X's)
0.10
0.05
0.00
-0.05
June 9th
July 7th
Aug 4th
Sep
20
15
10
5
0
windspeed [m/s]

EDDIES Summary

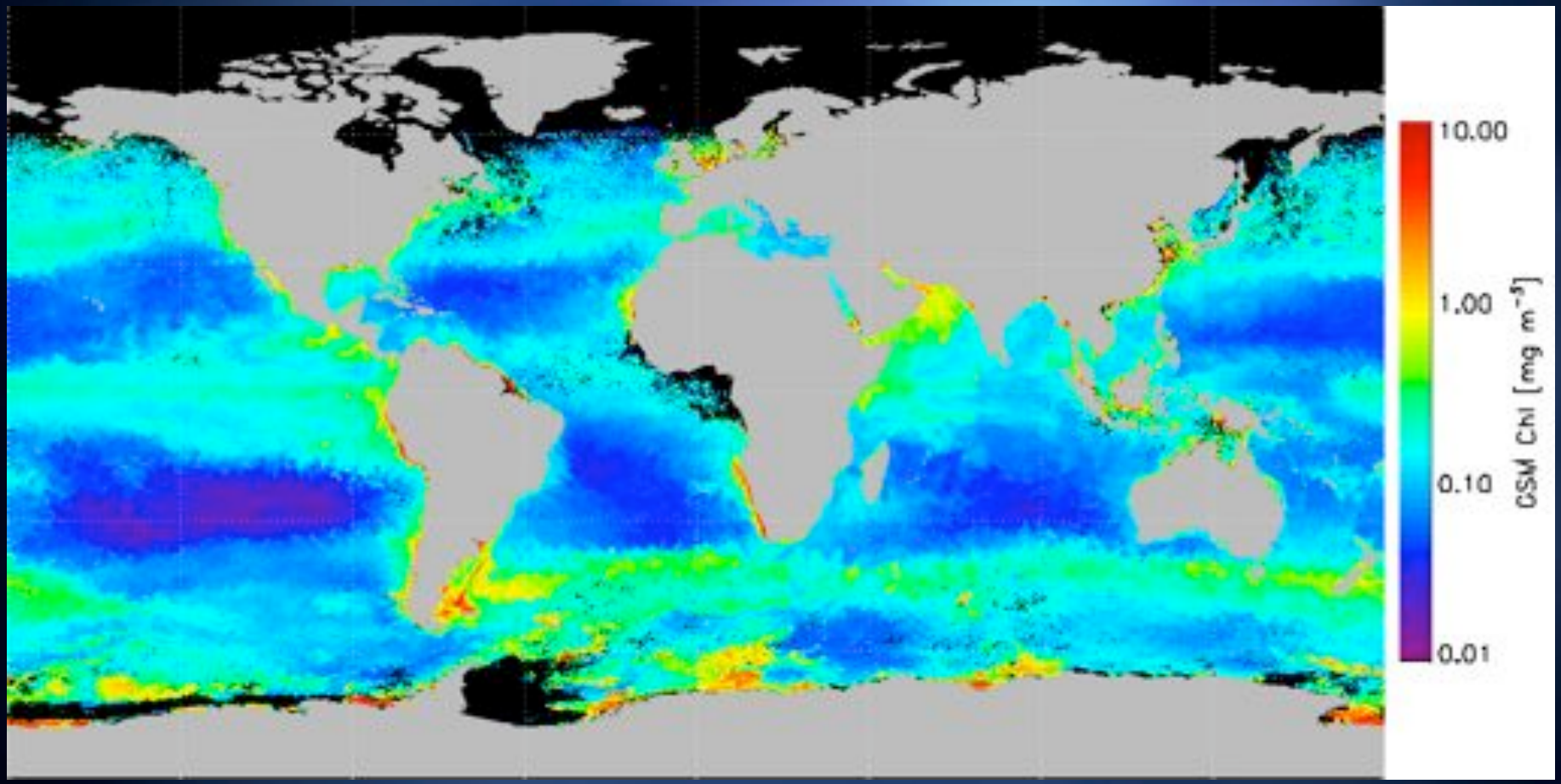
- Merged SeaWiFS & Aqua imagery provide an eddy centric view of anticyclone A4
- Anticyclone A4 shows effects of both eddy advection & eddy-Ekman pumping
- Open ocean mesoscale eddies are not a one answer for all times thing…

NASA REASON future developments:

- Merge Terra data if/when available
- More validation and analyses of the merged products
- More user-friendly interface
- sub-sampling, slicing
- More integration into NASA Giovanni system
- New products

ftp://ftp.oceancolor.ucsb.edu/pub/org/oceancolor/REASoN

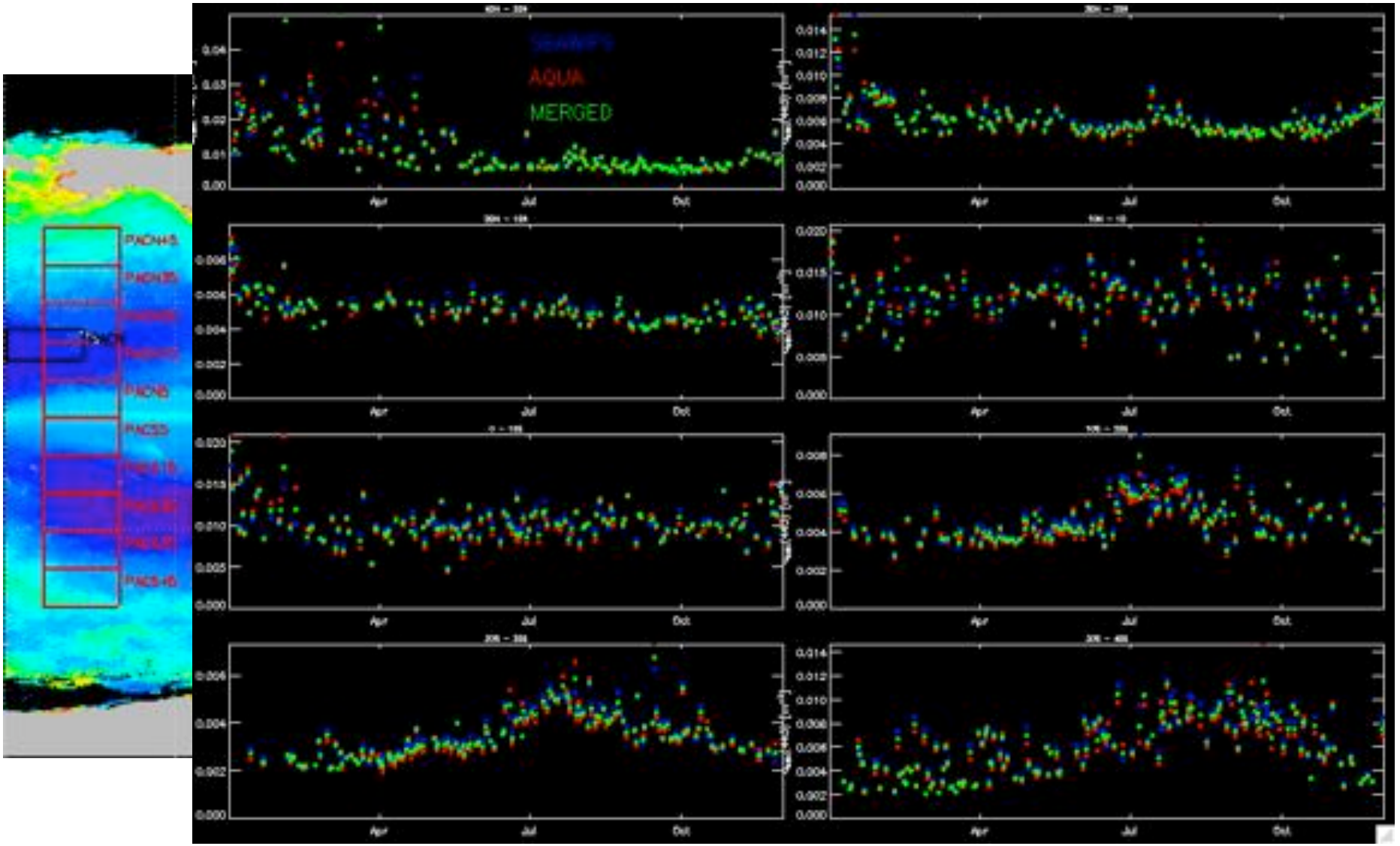
OPeNDAP http://dap.oceancolor.ucsb.edu/cgi-bin/nph-dods/data/oceancolor/



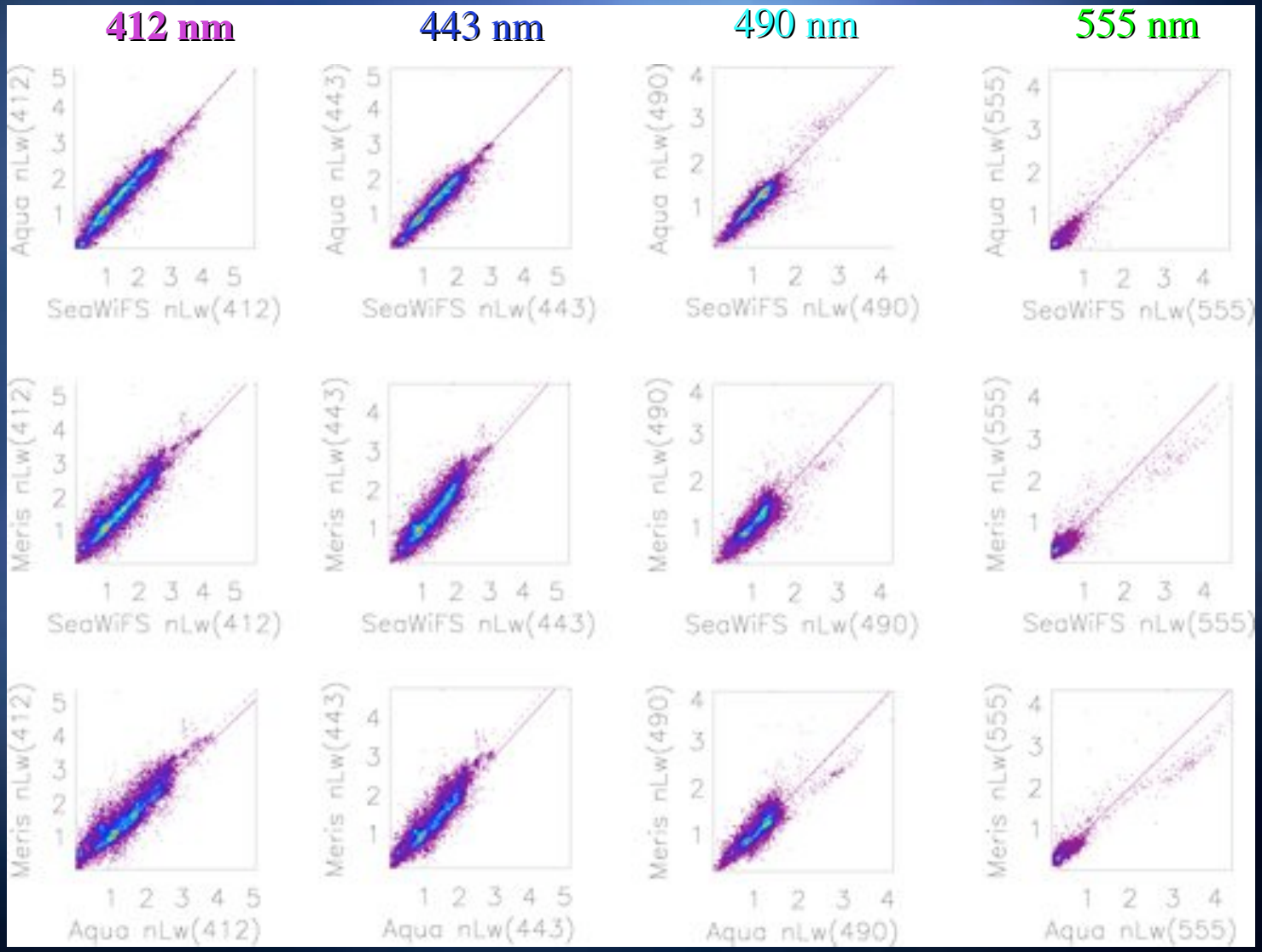
Merged SeaWiFS + Aqua Monthly CHL - February 2004

$a_{cdm}(443)$ - latitudinal comparison

SeaWiFS Aqua Merged

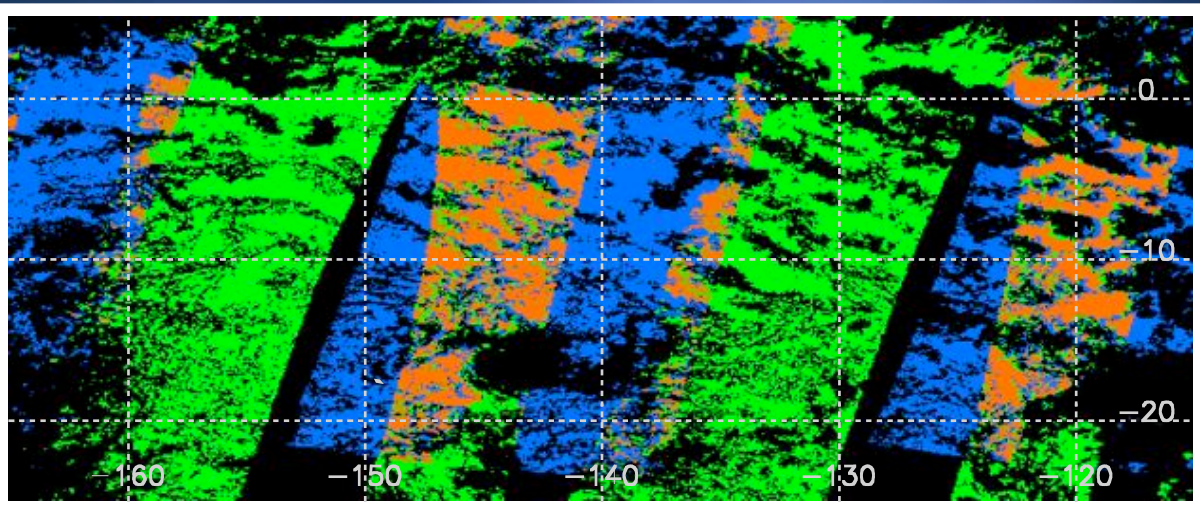


$L_{wN}(\lambda)$ comparisons (Jan. 1, 2003)



GSM Merging Model

Coverage map



Chl product