Empirical algorithm for global chlorophyll: Is it really that "bad"?

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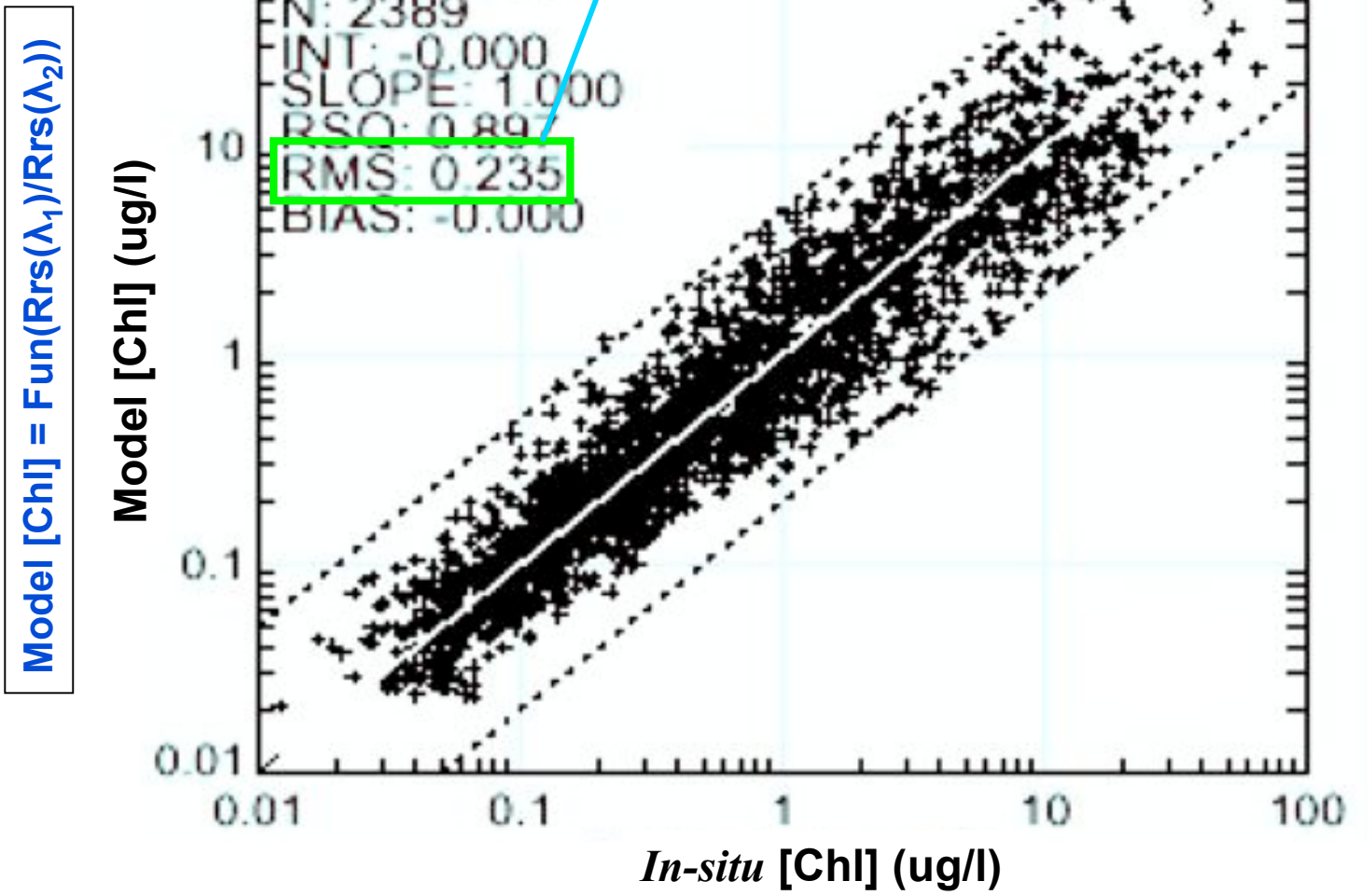
Motivation:

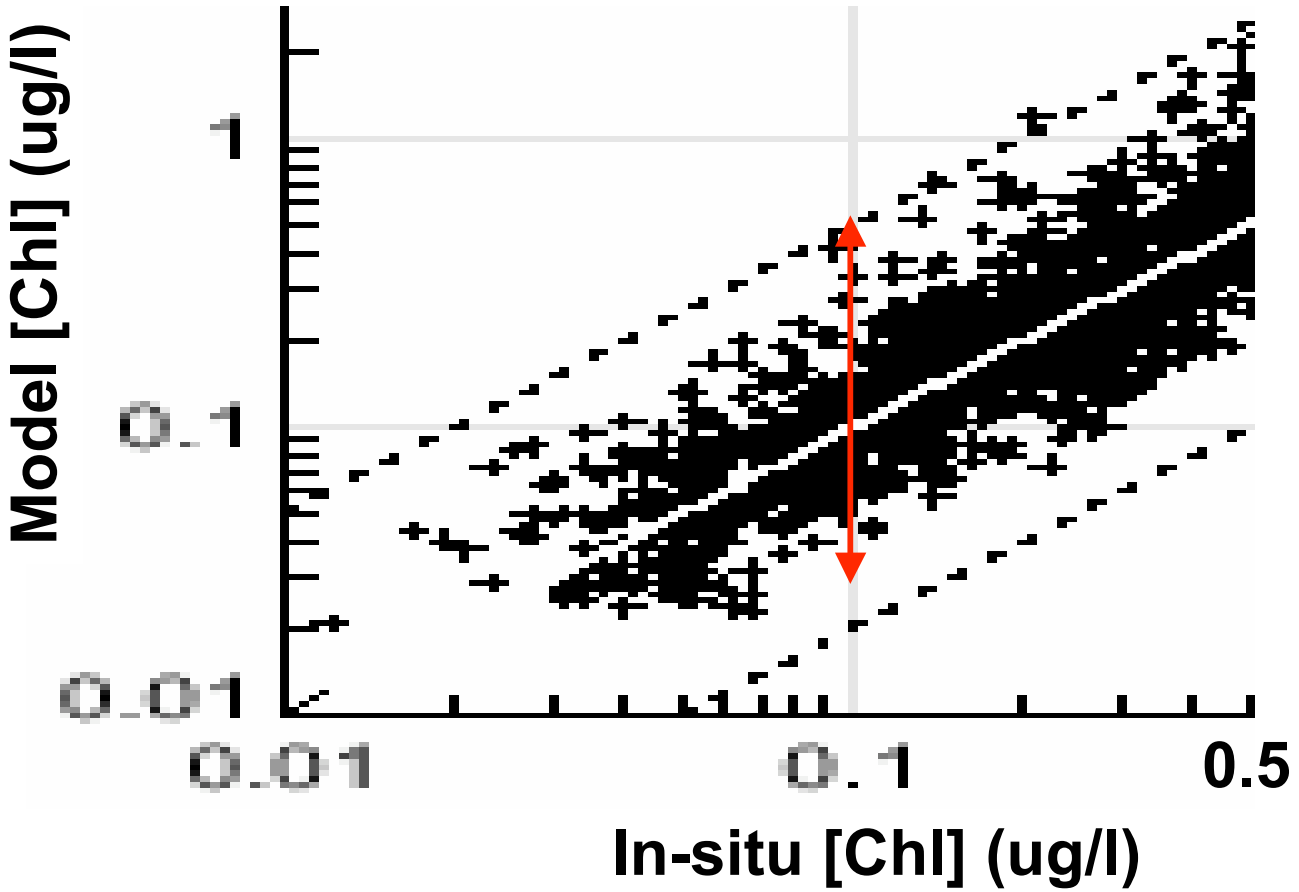
Model is ~1.7 times higher or lower than *in-situ*.



(*O'Reilly*'s OC4v5)

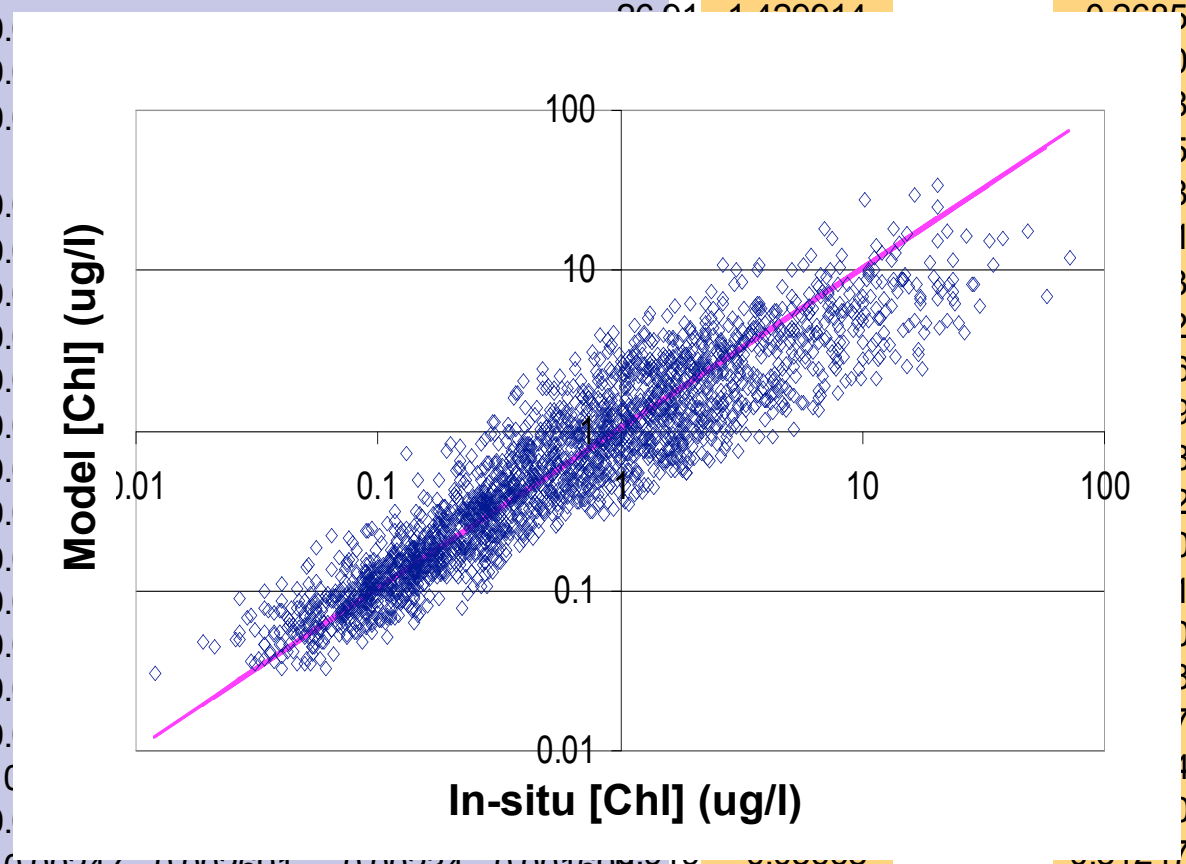
Oceanic waters

Nonlinear scaling of total absorption



Q: How much of these dispersion are natural?

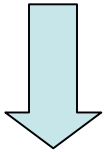
[Chl]	[Chl]	Rrs443	Rrs489	Rrs510	Rrs555	log([Chl])	log(rr_max)	rr_max	
38.19	38.19	0.001686	0.003293	0.004036	0.007479	1.58195	-0.26789	0.539644	
35.01	35.01	0.001384	0.002173	0.002499	0.004152	1.544192	-0.22049	0.601879	
26.91	26.91	0.001185	0.001843	0.002288	0.004246			0.53886	
47.96								0.524778	
23.55								0.6794	
23.97								0.715184	
19.15								0.600039	
33.46								0.548027	
17.32								0.689655	
10.12								0.717385	
0.401								1.646516	
0.515								1.284376	
0.539								1.325207	
0.091								3.242857	
0.079								3.592568	
0.461								3.271292	
0.132								5.874929	
0.296								2.909639	
0.4								3.29818	
0.314								3.846339	
3.287								1.284128	
0.919								2.05341	
1.741		0.00247	0.002691	0.00234	0.001699	1.741 0.240799	0.19972	1.583873	



(*OBPG* NOMAD subset)

Assumptions:

1. Data has '**enough**' representation
2. Data has '**good**' quality
3. '**Normal**' distribution of errors



Impression:

Empirical algorithm for global chlorophyll produces '**bad**' results, even for oceanic waters.

Explicitly or implicitly, the large dispersion is viewed as algorithm "error".

Sources of "error":

1. Natural (optical, bio-optical) variations
2. Algorithm
3. **Data imperfection**

Source of imperfection:

Measurement methodology
In-homogeneity (horizontal and vertical)
Sample handling
Data processing
etc

What is the algorithm error if data *inconsistency* is removed?

Filter out 'bad' data — Easy for obvious or extremes; but difficult for all others.

Re-analyze existing data (NOMAD)

Between [Chl] and Rrs, how mutually consistent are they?

Only when [Chl] and Rrs are consistent, can it possible to use Rrs ratio to infer [Chl].

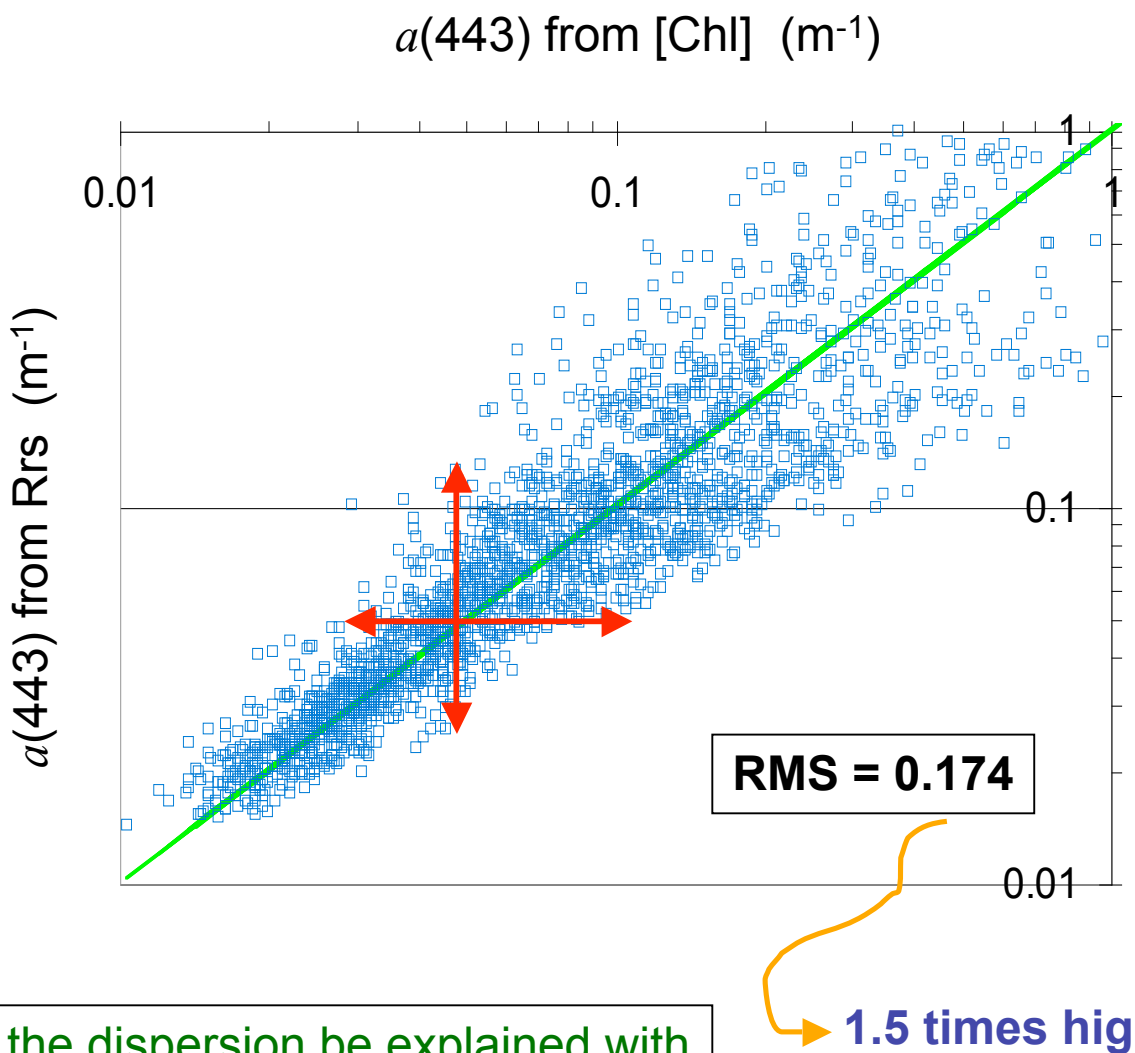
[Chl] → $a(443)$

(Case-1, *Morel and Maritorena*, 2001)

Rrs → $a(443)$

(QAA_v4, *Lee et al.,* 2007)

Scenario 1:
Both {[Chl]} are {Rrs} were measured perfectly and are assumed mutually consistent.



How much can the dispersion be explained with a **minimum** "correction" on data imperfection?

Environment/procedure of *in-situ* measurements

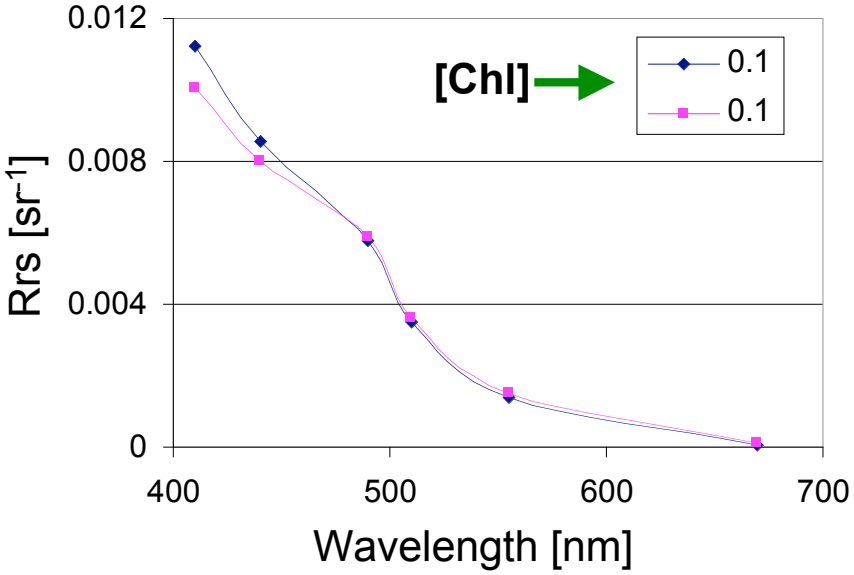
"[Chl] is accurate, to the best, within ±**35%.**"

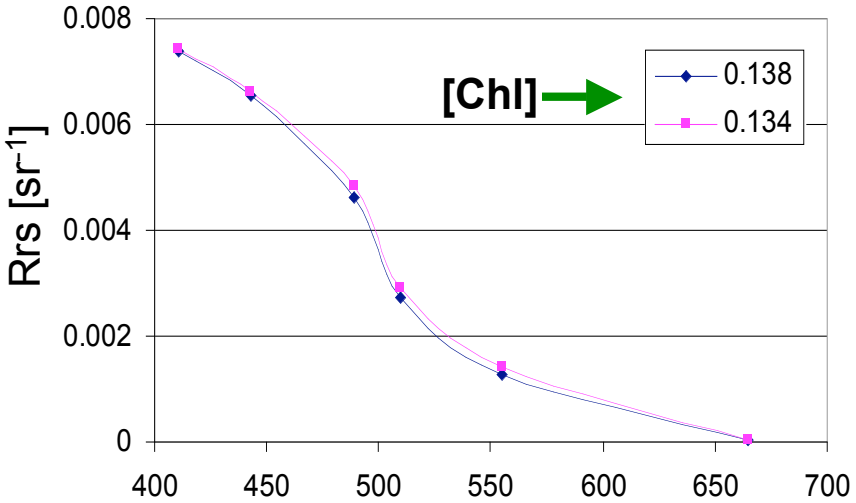
[Chl]

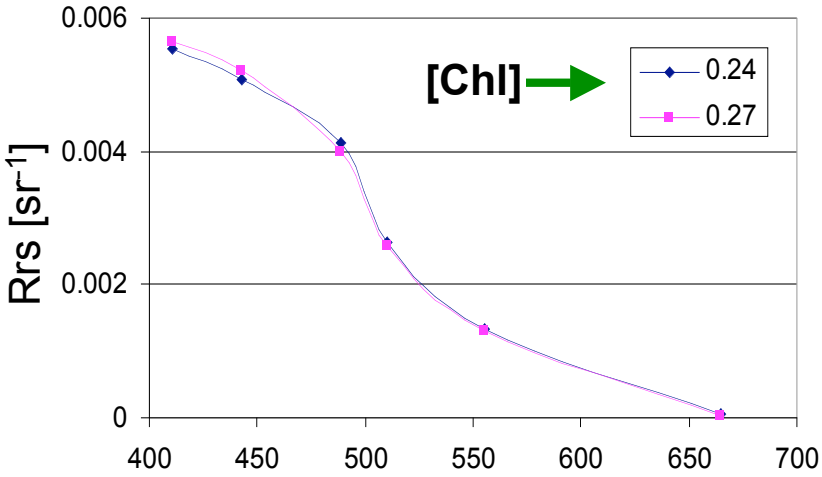
Rrs is easy to be off by ±**10%.**

Rrs

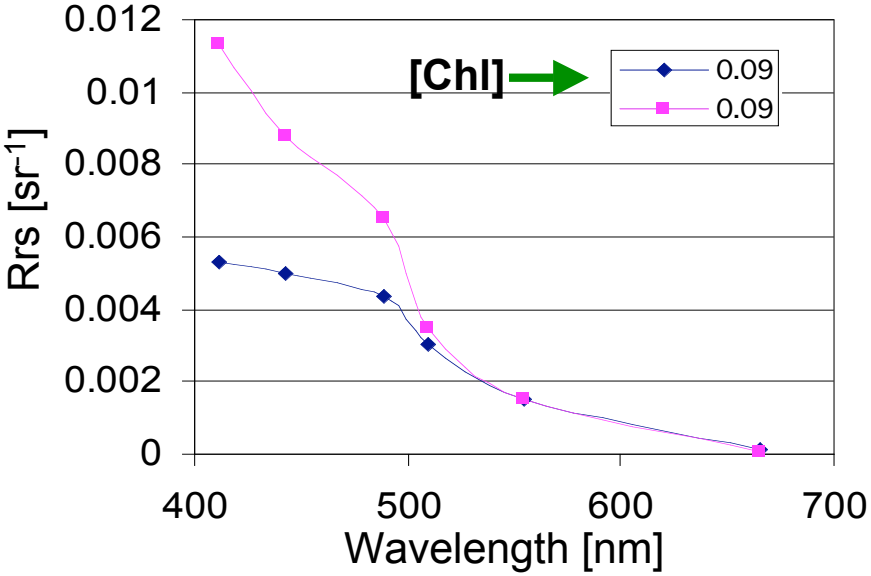
Mutually consistent data

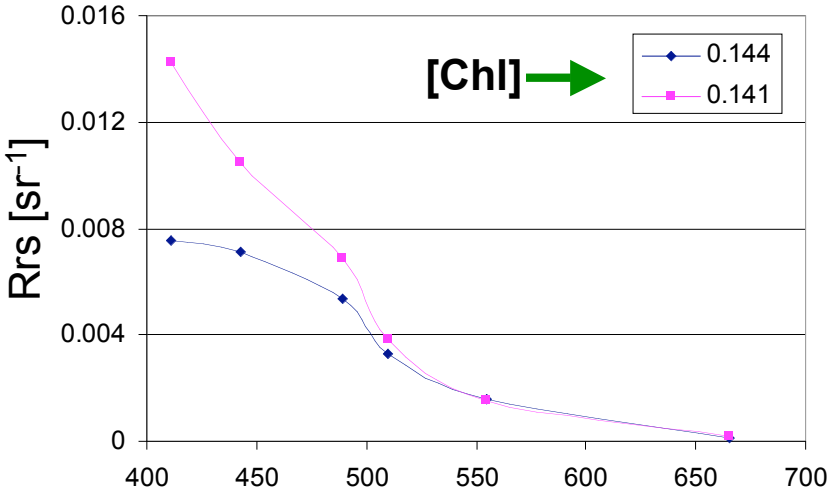


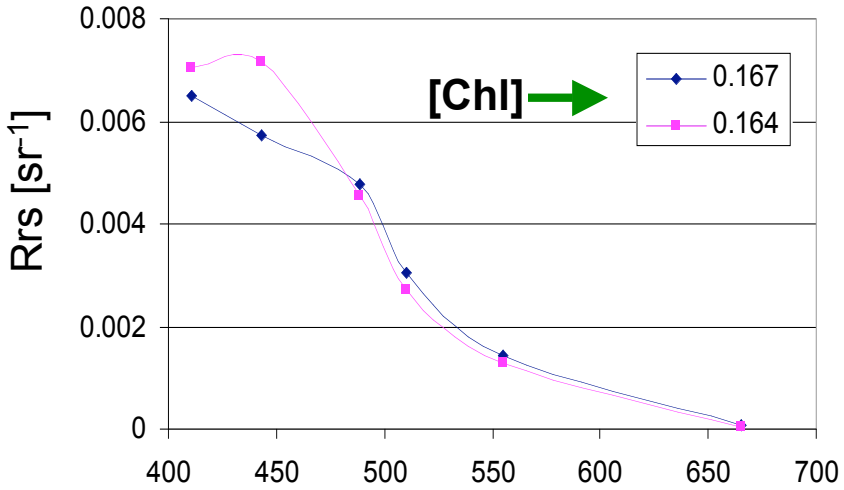


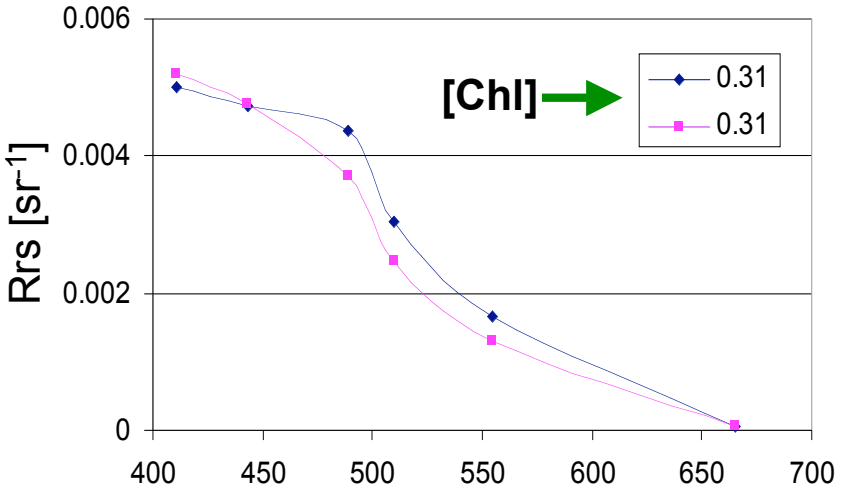


Similar [Chl], quite different Rrs

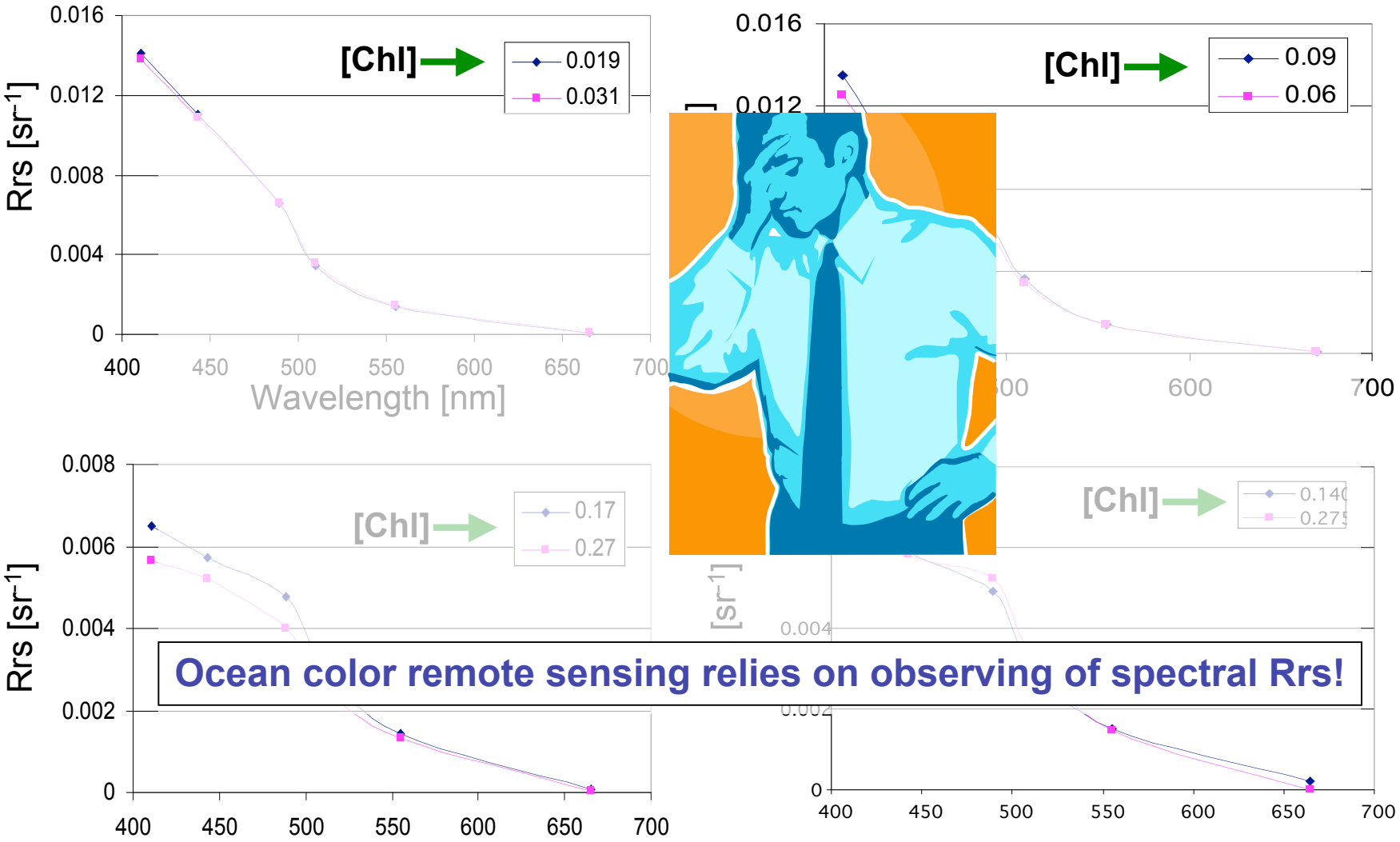








Similar Rrs, quite different [Chl]



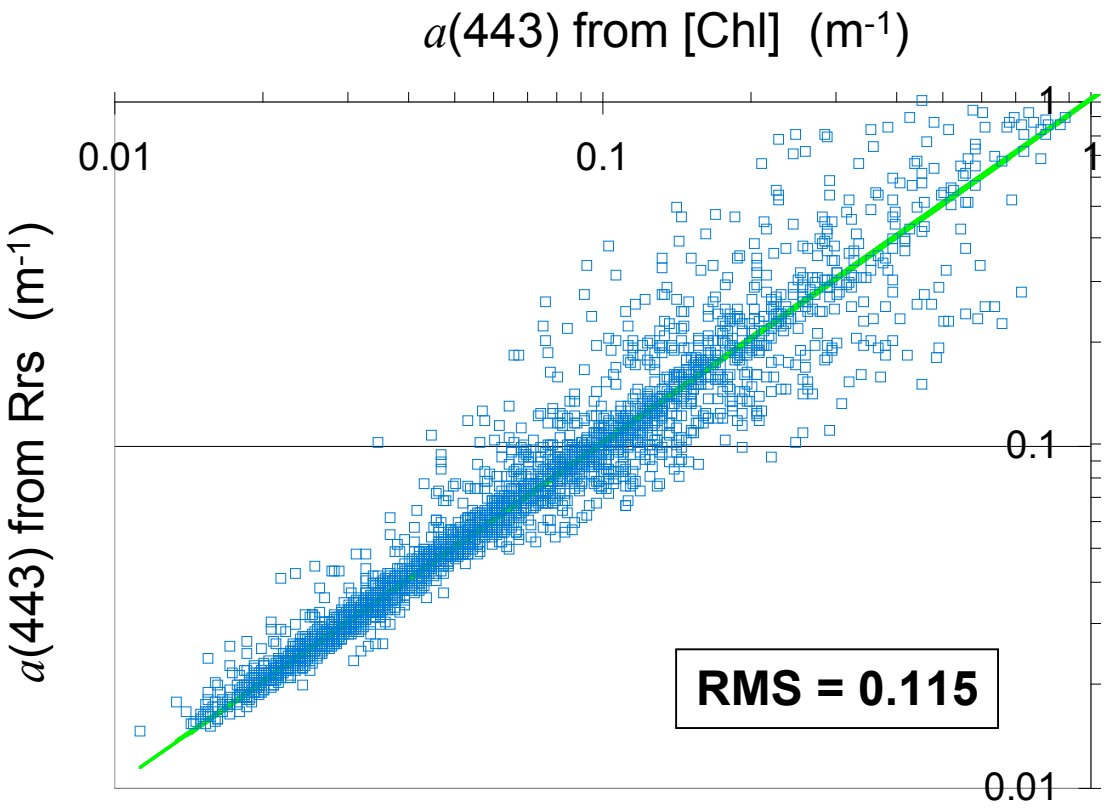
Ocean color remote sensing relies on observing of spectral Rrs!

Scenario 2: {Rrs} are ok, but {[Chl]} is imperfect.

Rrs no change,
[Chl] with ±35%

$1.35\{Chl\}$ → {a(443)}
$\{Chl\}$ → {a(443)}
$0.65\{Chl\}$ → {a(443)}

$\{Chl\}$ ⟷ {a(443)} ← {Rrs}



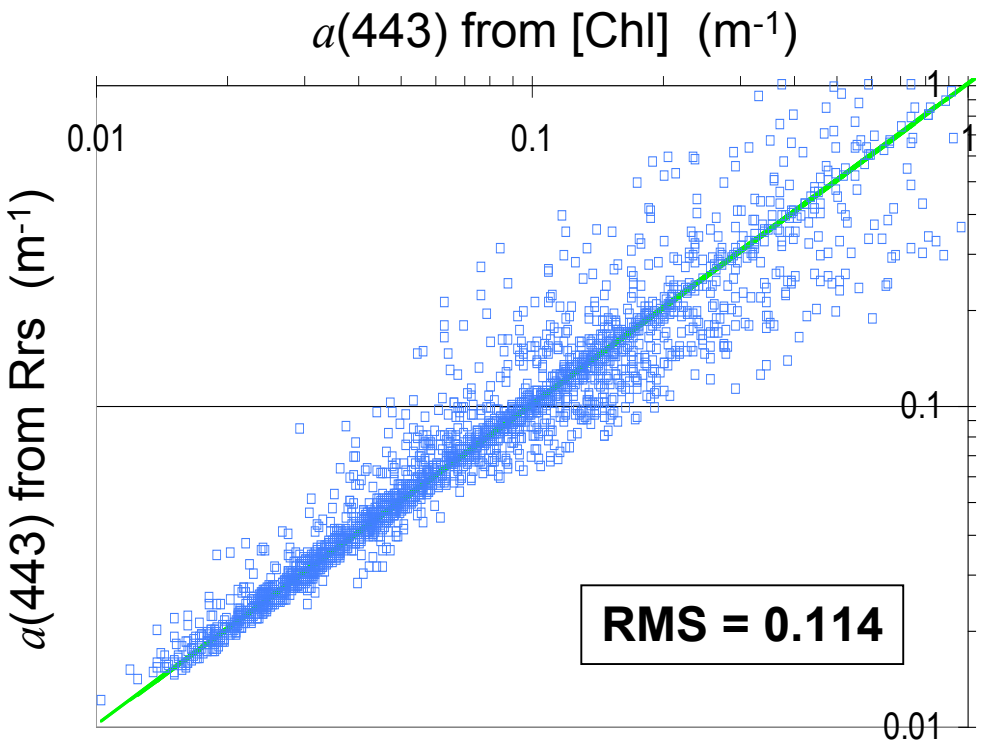
Scenario 3: {[Chl]} in ok, but {Rrs} is imperfect.

[Chl] no change,
Rrs with ±10%

$\{[Chl]\}$ → {a(443)} ⟺

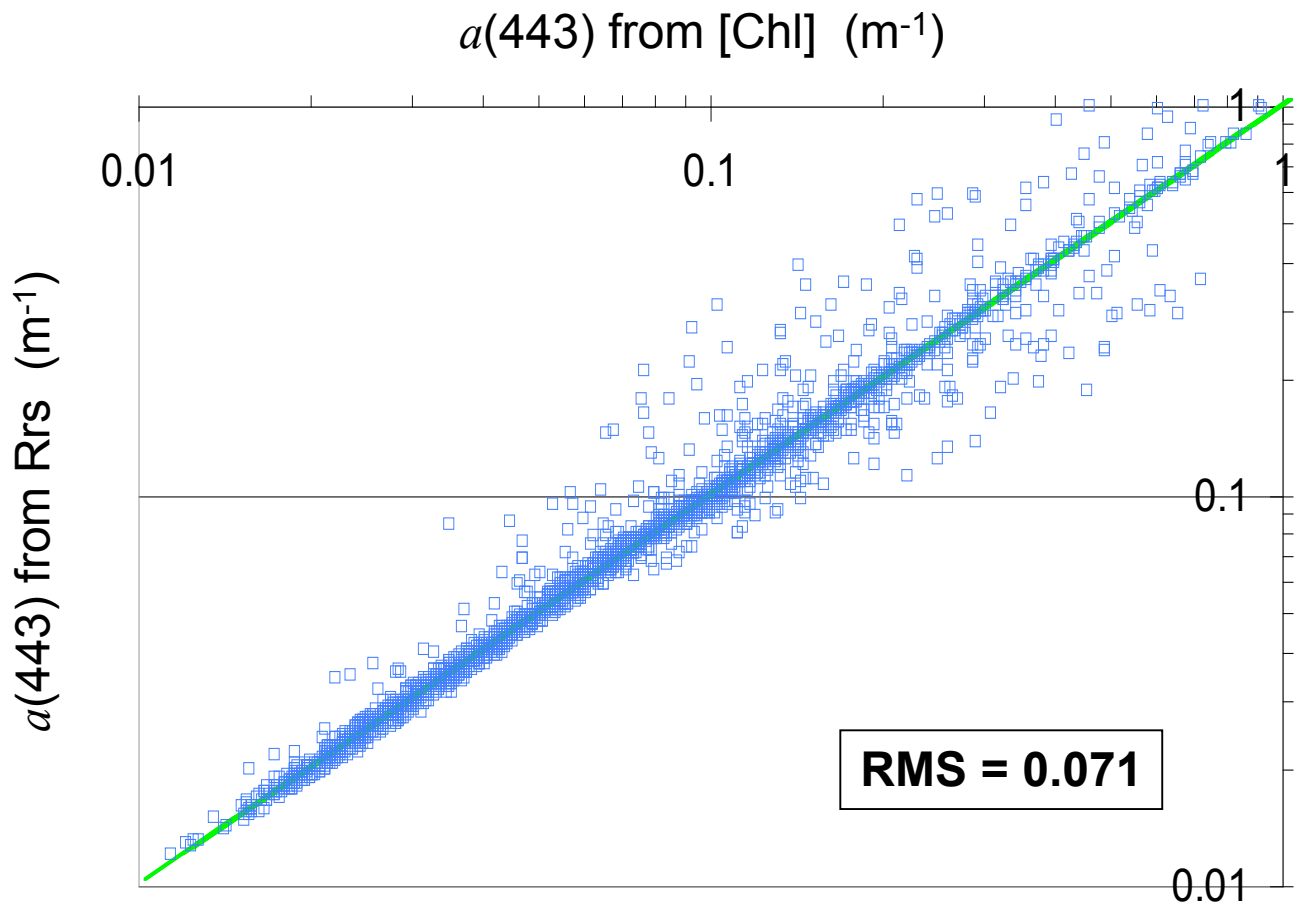
Factors applied to Rrs at

	443	490	555
{a(443)} ←	{1.1;	1.1;	0.9}
{a(443)} ←	{1.1;	0.9;	0.9}
{a(443)} ←	{1;	1;	1}
{a(443)} ←	{0.9;	0.9;	1.1}
{a(443)} ←	{0.9;	1.1;	1.1}



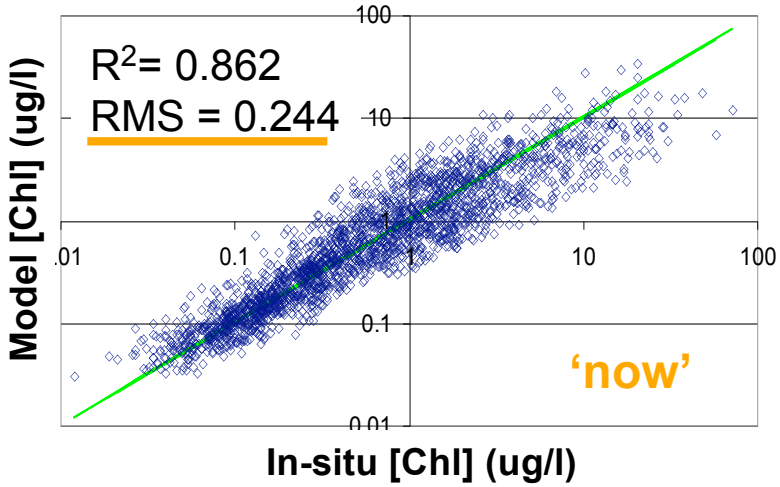
Scenario 4: Both {[Chl]} and {Rrs} are imperfect.

Rrs with ±10%, [Chl] with ±35%

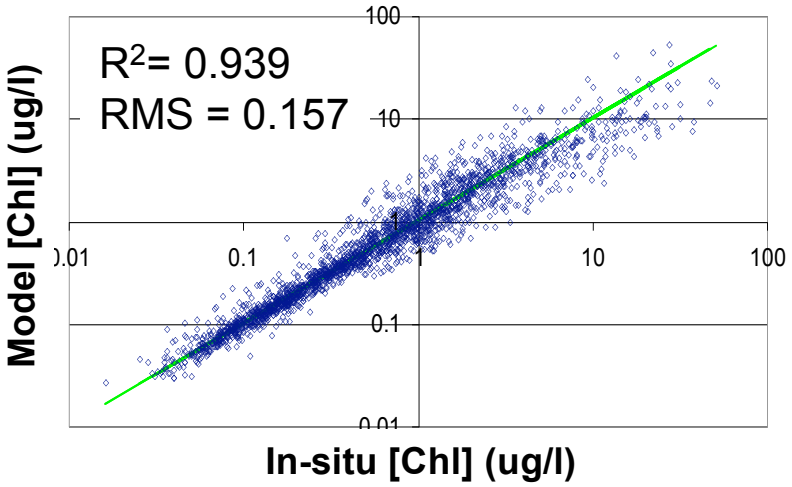


Effects to empirical algorithm for [Chl]

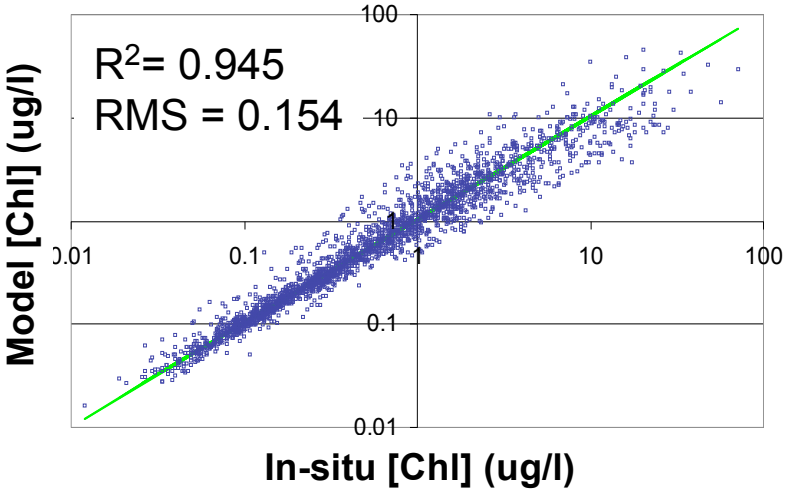
S1: Original data



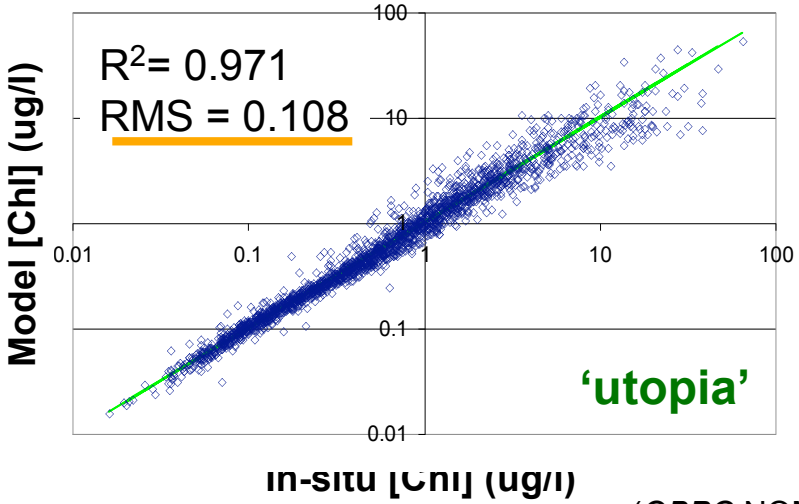
S2: Rrs no change, [Chl] with ±35%



S3: [Chl] no change, Rrs with ±10%



S4: Rrs with ±10%, [Chl] with ±35%



(*OBPG* NOMAD subset)

Summary of RMS

	$a(443)$	[Chl]
Scenario 1	**0.174**	0.244
Scenario 2	0.115	0.157
Scenario 3	0.114	0.154
Scenario 4	**0.071**	0.108

overall dispersion

More than a factor of 2 reduction in RMS.

~ lest algorithm contribution

The message:

1. “Bad” or **less-consistent** data could contribute ~**half** of the overall **dispersion** between sample-measured [Chl] and Rrs-derived [Chl].

   → This conclusion may be applicable to IOP products also.

2. For ***consistent*** measurements, simple ratio derived [Chl] is not as ‘bad’ as it is appeared now, especially for oceanic waters with low [Chl] (< ~0.5 mg/m3).

   → **Semi-analytically derived [Chl] will be even better as other optically active constituents are separated.**

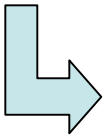
3. Improvement on measurement accuracy and data **consistency** are critical for validating and understanding algorithm (either for [Chl] or IOPs, etc) performance.

   → To understand/quantify error propagation, it is necessary to separate algorithm error from the overall dispersion.

   → Data-based algorithm will then be difficult.

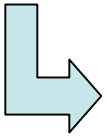
The message cont.:

4. For waters with high [Chl] (> ~0.5 mg/m3), larger gap still exist between sample-measured and ratio-derived [Chl] even after "*correcting*" measurement "*errors*". Separation of the active optical components with semi-analytical models is required for improvement of accuracy and for understanding of error propagation.



Demands better understanding on the spatial and temporal variations of bio-optical properties.

5. [Chl] is an important ocean-color product, but **not ideal** for validating a remote-sensing system *if the ±35% minimum uncertainty is still exist*.



A property with less uncertainty from in situ measurements is desired for such purpose.

6. IOPs are not only important ocean-color products, can also serve as a quality check regarding consistency between [Chl] and Rrs values.