Level-3 OC product uncertainties: A brief review of issues

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IOCS Breakout 3 – Uncertainties
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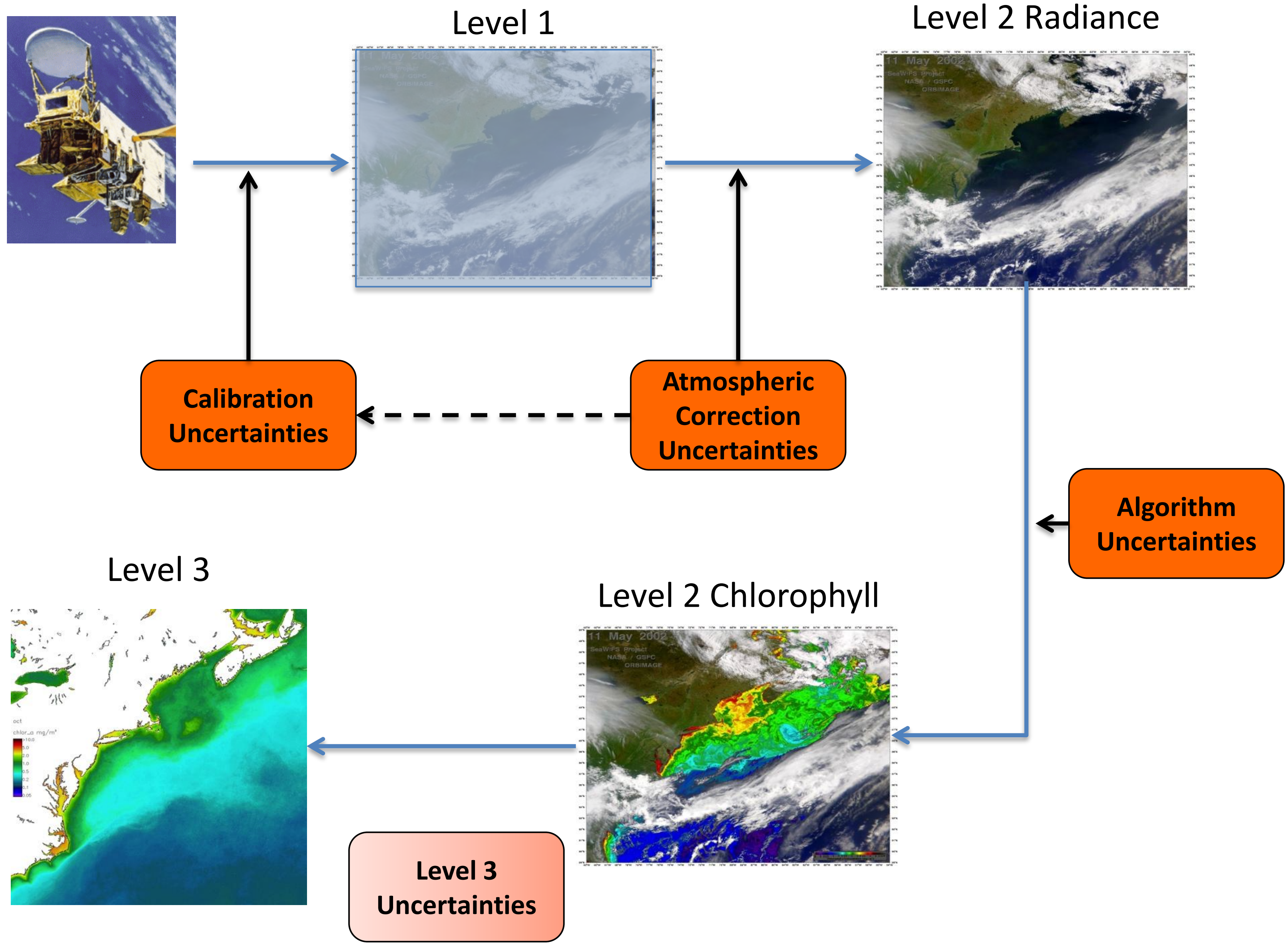
Level-3 Ocean Color Data

- Level 3 data are derived geophysical variables that have been aggregated/projected (gridded, binned) onto a defined spatial grid.

- These include any image data that have been spatially or temporally mapped/binned.

- Examples: Global Chlorophyll product at daily, 8-day or monthly resolution.

- Probably the most widely used OC products for the majority of users.



Level 1
Level 2 Radiance
Calibration Uncertainties
Atmospheric Correction Uncertainties
Algorithm Uncertainties
Level 3
Level 2 Chlorophyll
Level 3 Uncertainties

Level-3 Gridded Data Uncertainty Issues

- What are the metrics for uncertainties?
  - Bias, standard deviation, RMS, relative error.
- What do users want for uncertainties?
  - The type of uncertainty statistic desired will depend on the user.
- How should gridded uncertainties be produced?
  -Uncertainties depend on properties that have spatial/temporal variability.
- How are uncertainties impacted by averaging?
  - Averaging, merging can reduce standard deviation but not bias.
- How can/will uncertainties be used for merging long-term data sets?

Users of Level-3 Data/Uncertainties

- *Inter-agencies:* Merging level-3 products from multiple sensors for long-term time series of CDRs.
- *Agencies* – how accurate are products? Do they meet mission requirements? Can they be used in CDRs?
- *Modelers* – what are input uncertainties so downstream product uncertainties can be generated/understood.
- *Algorithm Developers* – where can algorithms be improved? What are reasons for algorithm performance variations?
- *General users* – what is best product to use for my purposes?

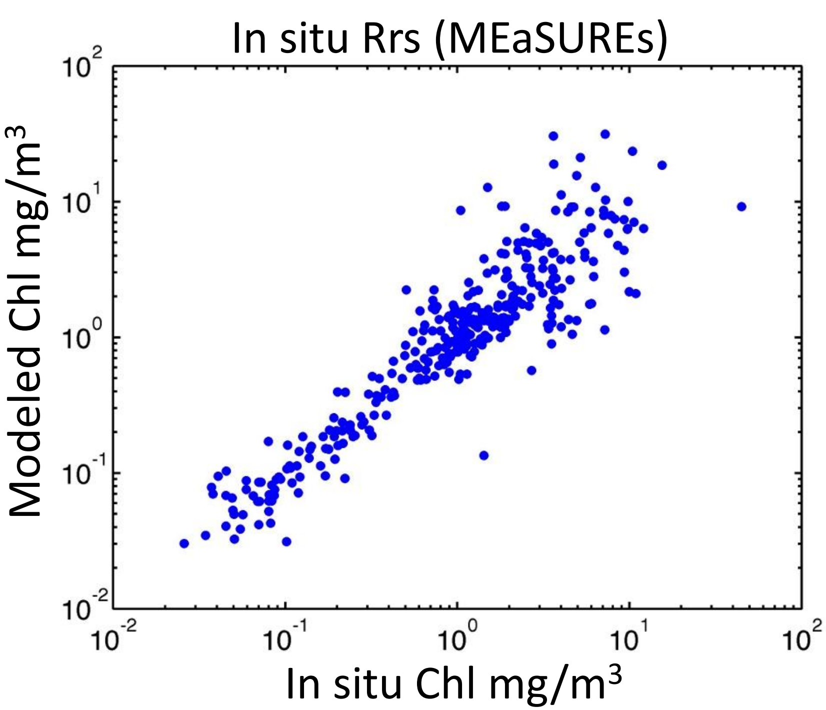
Users & Uncertainty Needs

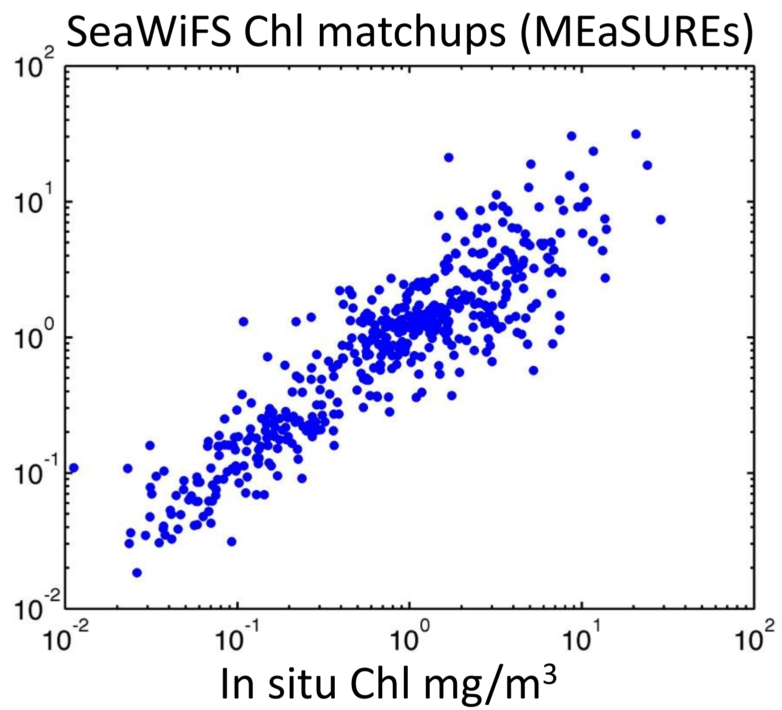
User	Requirement	Metric	Mapped?
Inter-Agency	CDR	Bias, Std. Dev.	Yes (if not removed)
Agency	Mission Product Performance	RMS, MPD, Bias	Yes
Algorithm developer	Algorithm Evaluation	RMS, Bias, MPD	Yes
Modeler	Assimilation	RMS, Bias	Yes
General User	Product reliability	MPD, ?	?

Uncertainty sources

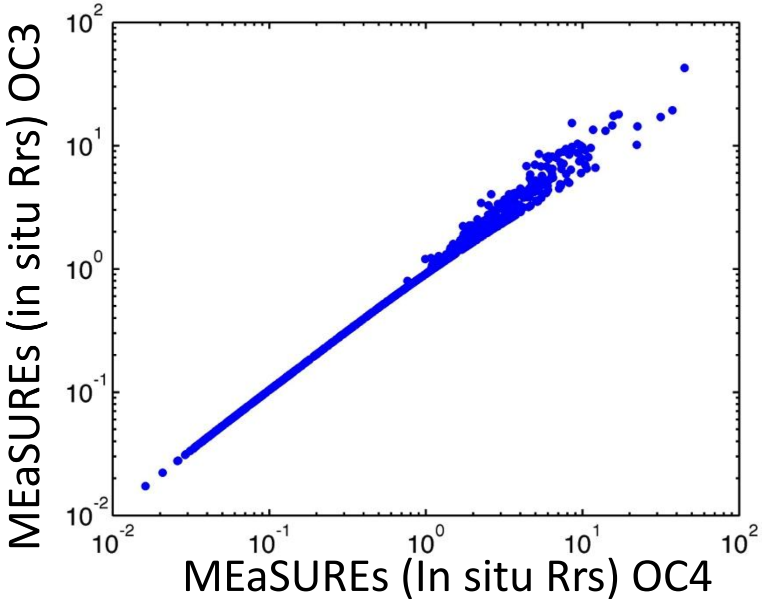
- Sources include algorithm (inversion errors), sensor noise (non-negligible error remaining after V.C.), radiance errors (A.C.), imperfections from time/space matchup differences.

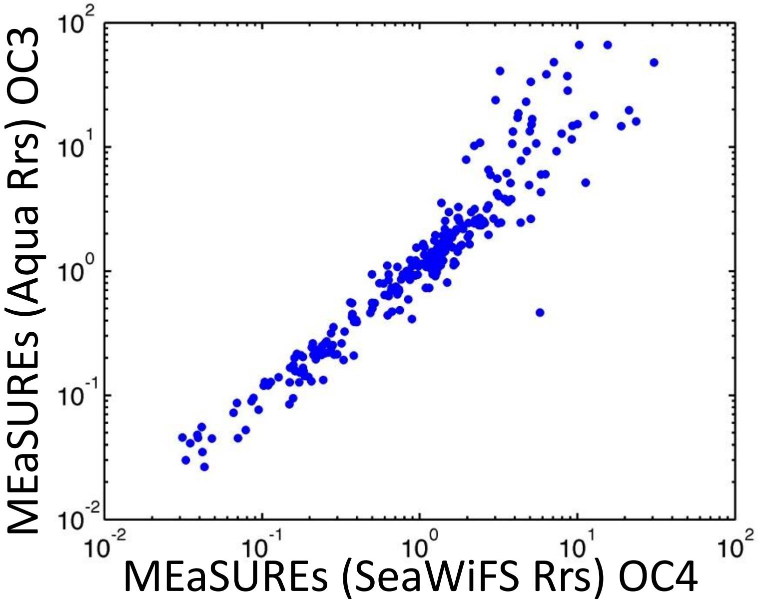
- Sources of uncertainty need to be identified & quantified in terms of overall Level-3 uncertainty (eg Salama and Stein, 2009).





Algorithm mismatches

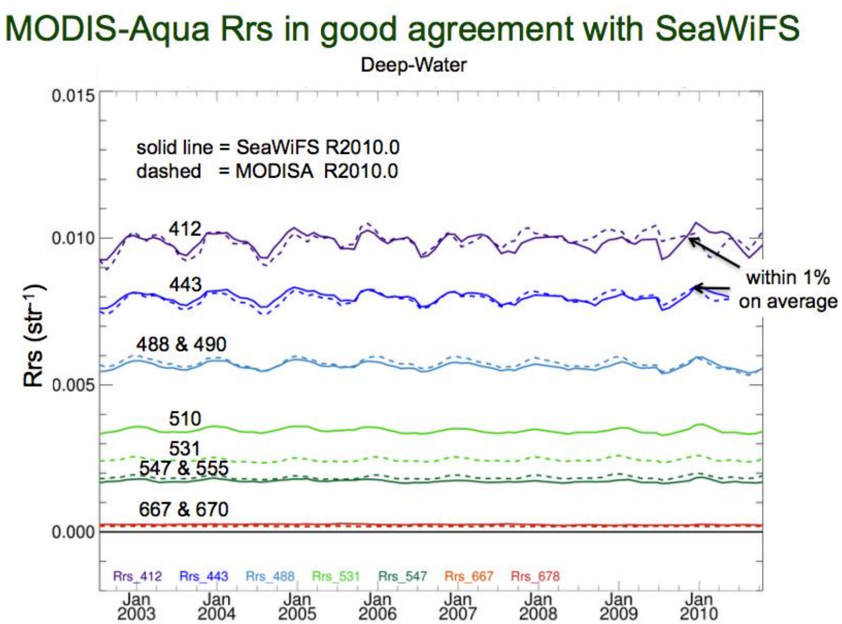




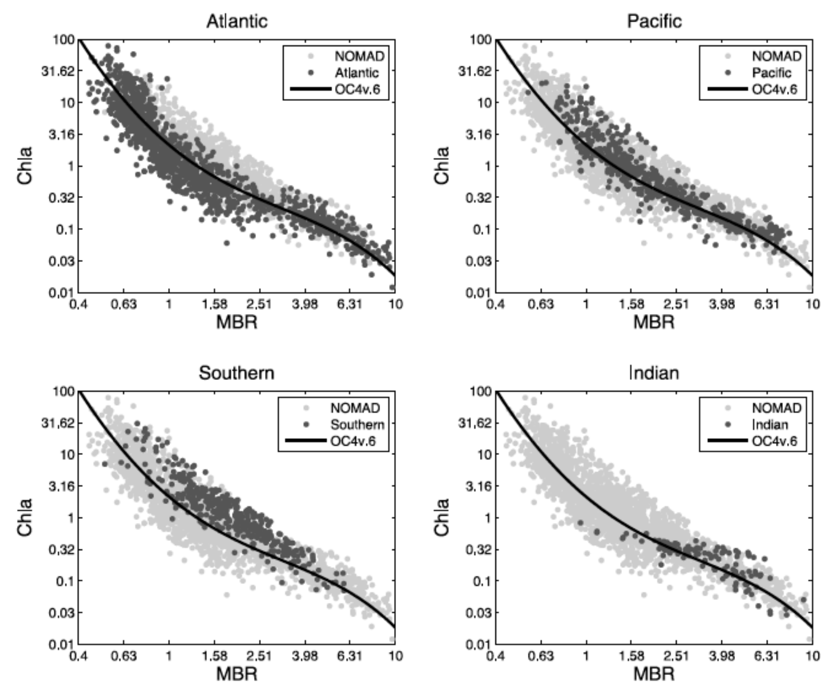
- Algorithm forms contribute to product differences based on wavelengths used.
- This impacts product comparisons and merging.

Level-3 Averaging/merging Issues

- Averaging data reduces *some* uncertainties
- Product bias remains and is a potentially huge challenge.
- How can/should inter-product bias be assessed/removed?
- Are regional/geographic biases significant?
- Essential to remove bias for CDRs.



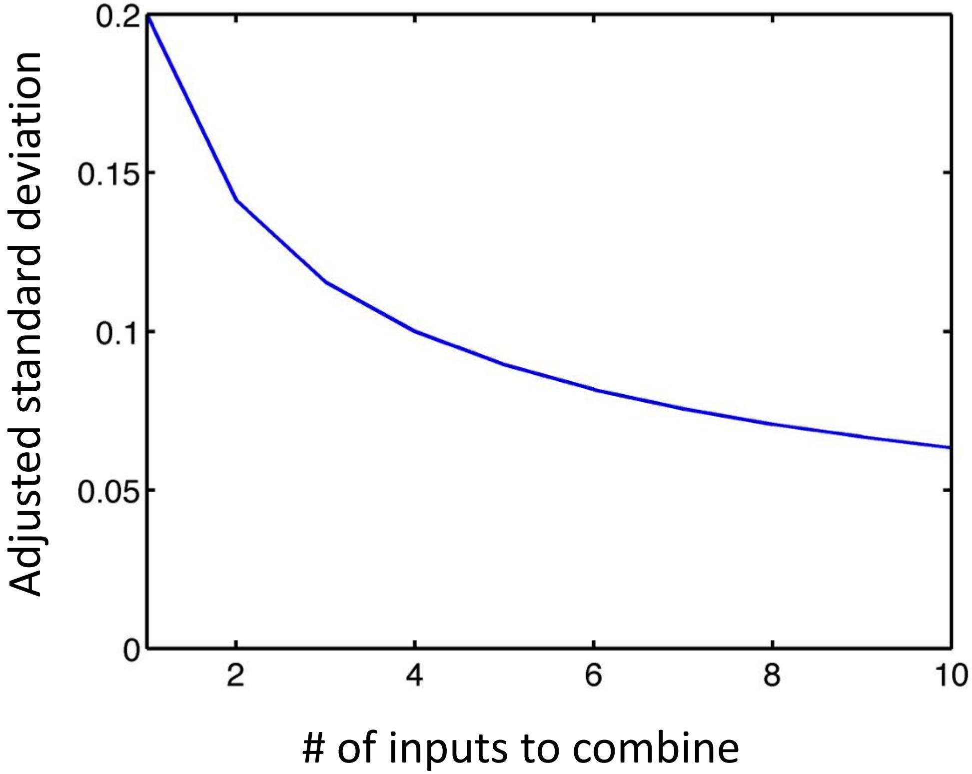
Franz, 2012



Szeto et al, 2011

Hypothetical chlorophyll averaging/merging

$$\sigma_{av} = \frac{1}{\sqrt{\sum w_i}}$$



$$Chl_{av} = \frac{\sum w_i Chl_i}{\sum w_i}$$

$$w_i = \frac{1}{\sigma_i^2}$$

- Assuming multiple sensors with no bias and equal starting standard deviation of 0.2, adjusted/combined standard deviation (y-axis) decreases towards asymptotic state with increasing number of sensors (x-axis).
- Uncertainties should go down when combining multiple records from multiple sensors for same observation.

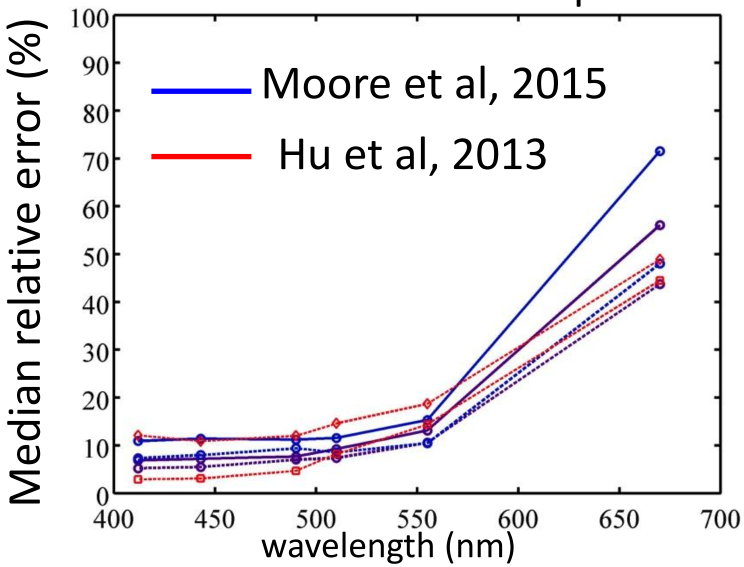
Methods for Characterizing OC Uncertainties

- Bottum-up propagation from input data sources for error budgeting – confidence intervals, ensemble methods
  - Wang et al 2005
  - Lee et al., 2010;
  - Maritorena et al. 2010;
- Match up evaluation
  - Bailey et al, 2008
  - Antoine et al. 2008
  - Moore et al. 2015
- Bayesian
  - Frouin and Peletier, 2015
  - Salama and Stein, 2009
- Satellite-satellite evaluations
  - Melin, 2010
  - Hu et al, 2013

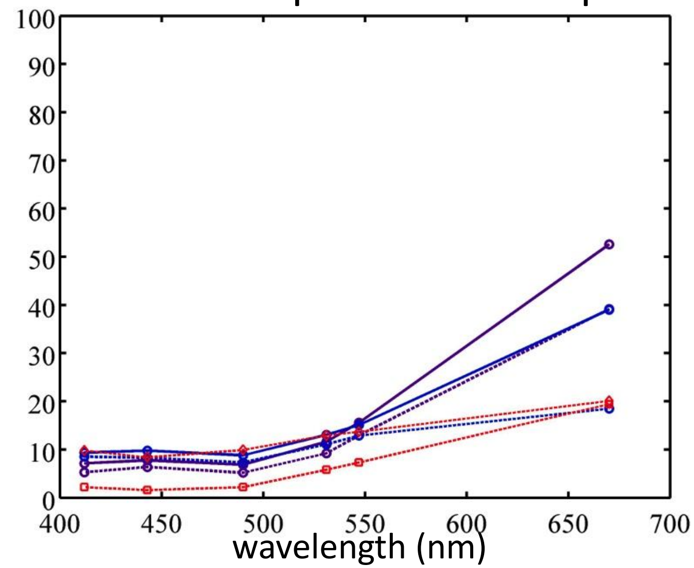
Methodology comparisons:
How well do different methods agree?

Example: Estimating Rrs uncertainties

SeaWiFS Rrs matchups



Modis-Aqua Rrs matchups



from Moore et al., 2015 (RSE)

Key questions …

- What are the key metrics for representing level-3 product uncertainty?
- How should they be calculated?
- What are the existing and desired levels of uncertainties for OC products?
- How can they be mapped as products themselves?
- What information is needed to derive uncertainties?
- How are multiple approaches to be reconciled?
- Is in situ matchup validation the only way to determine bias in products?