ACE Ocean Science & Radiometer Requirements

IOCCG Level-1 Working Group Meeting
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NASA/GSFC

NASA Ocean Biogeochemistry Derived Products & CDRs

- CDRs drive sensor stability and derived product accuracy requirements
- Ocean Products
  - **Multispectral normalized water-leaving radiances (±5%)**
  - **Chlorophyll-a (± 35%)**
  - **Diffuse attenuation coefficient (490 nm)**
  - **Primary production**
  - **Inherent optical properties (IOPs; spectral absorption & scattering coefficients)**
  - **Spectral diffuse attenuation**
  - **Spectral remote sensing reflectance (pending a hyperspectral sensor)**
  - **Particulate organic carbon concentration**
  - **Calcite concentration**
  - **Colored dissolved organic matter (CDOM)**
  - **Photosynthetically available radiation (PAR)**
  - **Fluorescence line height (FLH)**
  - **Euphotic depth**
  - **Total suspended matter**
  - **Trichodesmium concentration**
  - Particle size distributions & composition (biogenic, mineral, etc.)
  - Functional/taxonomic group distributions
  - Phytoplankton carbon
  - Dissolved organic matter/carbon (DOM/DOC)
  - Physiological properties (e.g., C:Chl, fluorescence quantum yields, growth rates)
  - Other plant pigments (e.g. carotenoids)
  - Export production

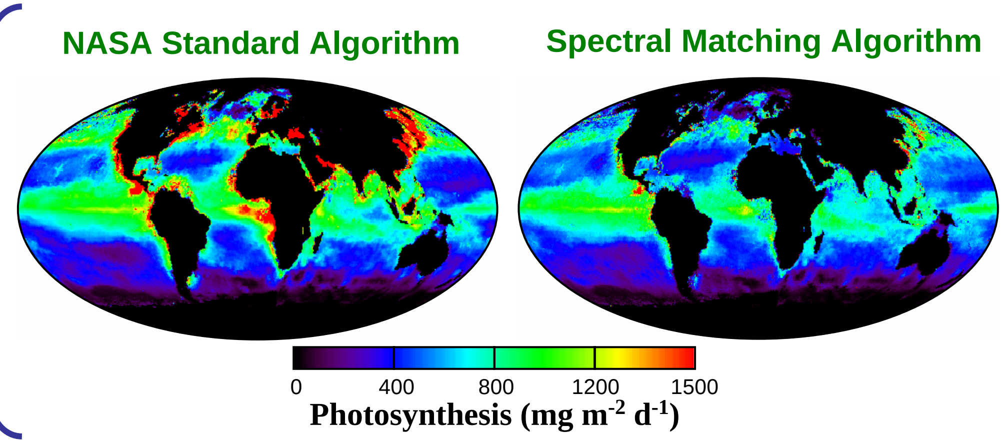
Current OBB CDRs

Candidate OBB CDRs

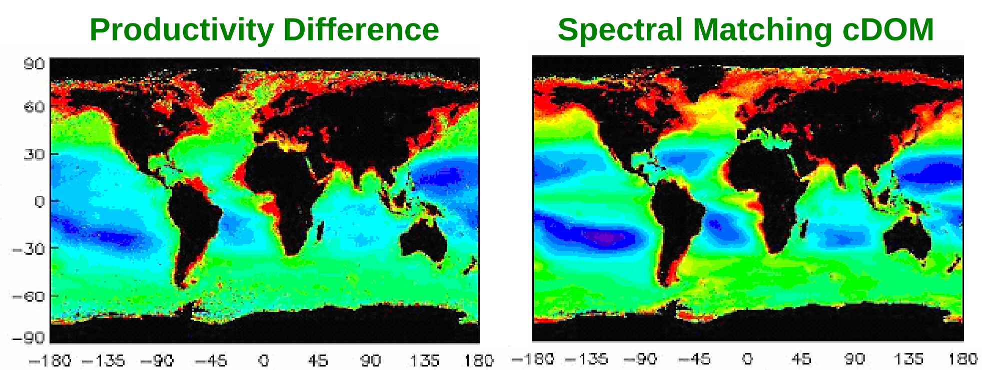
Research products

Impact of CDOM on Chlorophyll Retrieval and Primary Production

- Different chlorophyll algorithms that perform equally when compared to field data yield **global productivity estimates that differ by 16 billion tons of carbon per year.** This uncertainty is ten times greater than interannual trends detected over the entire SeaWiFS record.

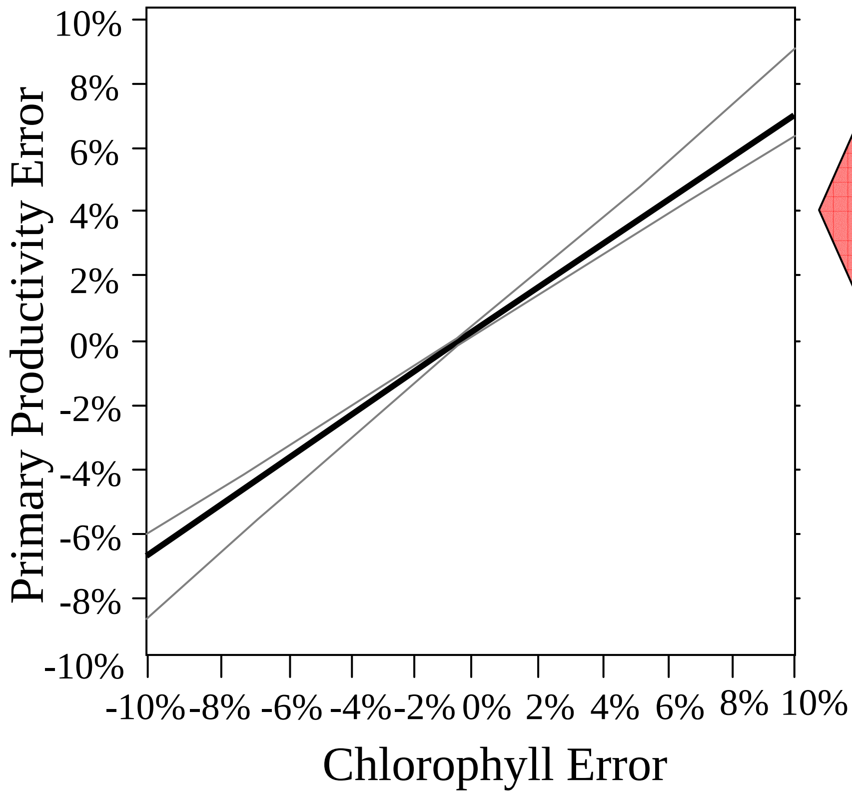


Primary productivity uncertainty due to chl-a uncertainty ~30%!



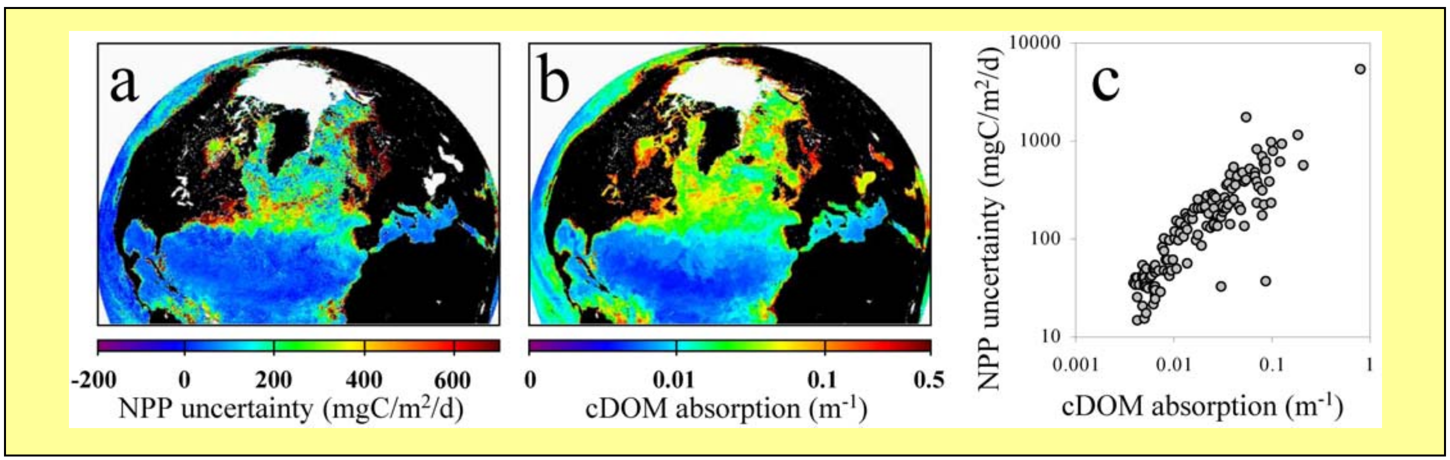
- This uncertainty in productivity largely reflects the inadequacy of heritage wavebands for separating different absorbing components.

Primary Production: Sensitivity to Chl Uncertainty

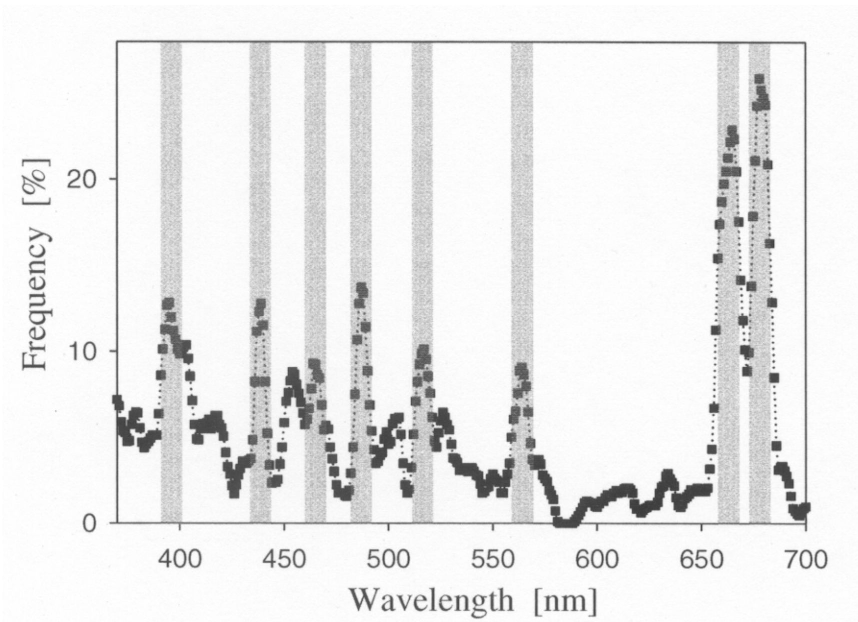


- Phytoplankton Net Primary Production (NPP) errors scale linearly with chlorophyll errors for standard NPP algorithms (i.e., not carbon-based)
- Relationship – NPP error = 0.7 Chl error

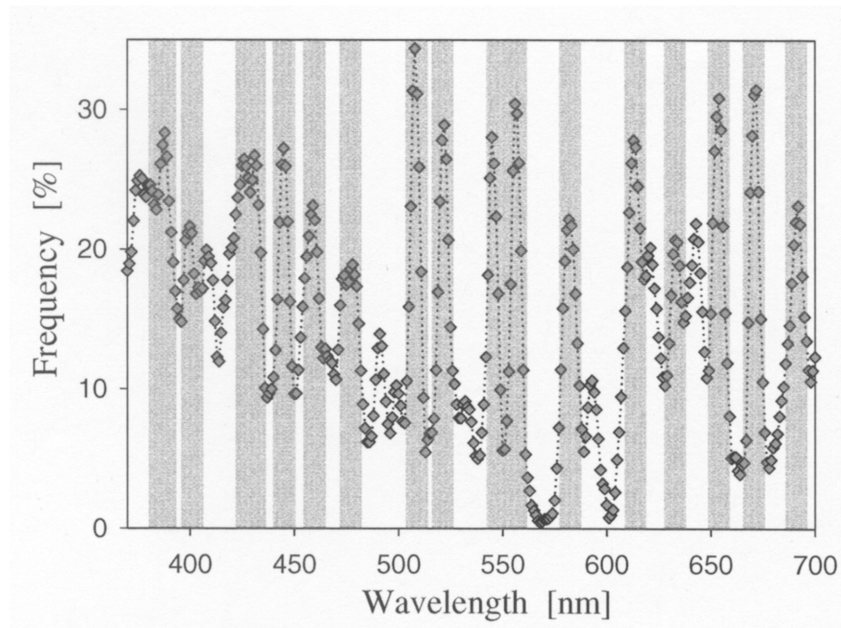
- Chlorophyll uncertainties are strongly influenced by uncertainties in cDOM absorption – *implying that improved cDOM retrievals (UV wavelengths) will improve NPP estimates*



Phytoplankton Functional Groups: Spectral Derivative Analyses



Spectral distribution of the frequency where the 1st-order derivative of ocean reflectance = 0.



Spectral distribution of the frequency where the 2nd-order derivative of ocean reflectance = 0.

Lee, Z-P., K. Carder, R. Arnone, & M-X. He, Determination of primary spectral bands for remote sensing of aquatic environments, *sensors*, 7, 3428-3441, 2007.

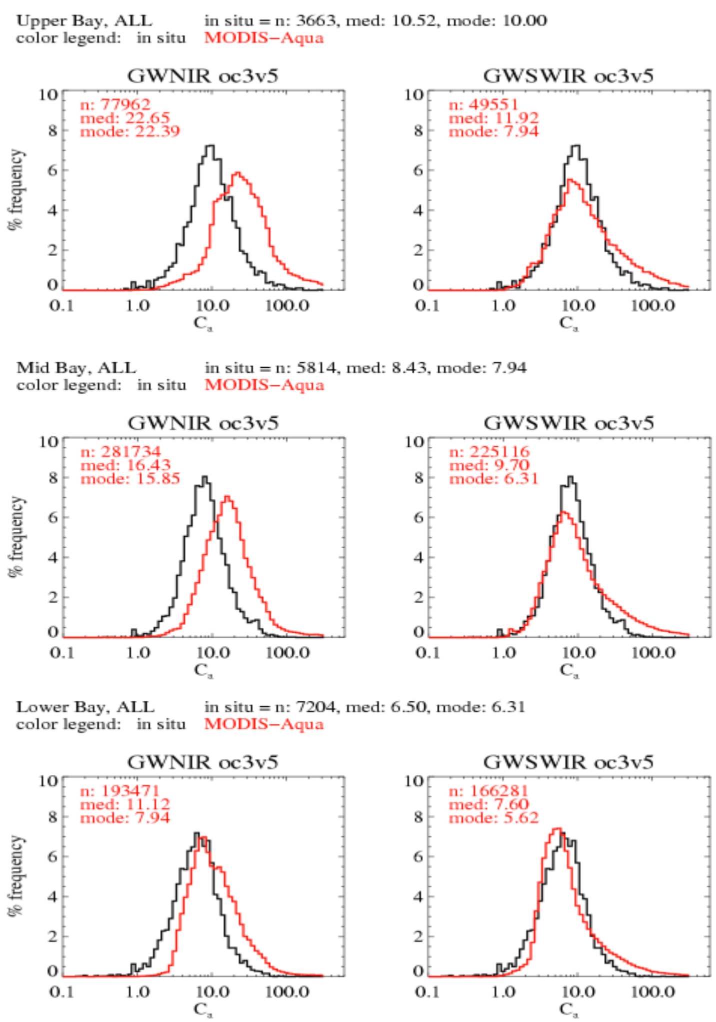
SWIR-based Corrections:
Impact on Chlorophyll Retrievals

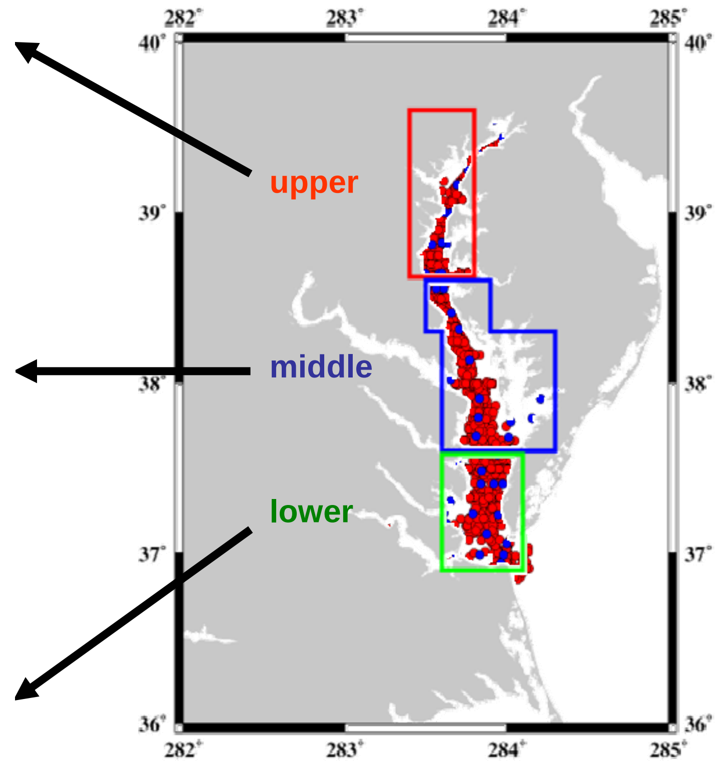
Chlorophyll (mode)

Field: 10 mg/m^3
w/o SWIR: 22 mg/m^3
w/ SWIR: 8 mg/m^3

Field: 8 mg/m^3
w/o SWIR: 16 mg/m^3
w/ SWIR: 6 mg/m^3

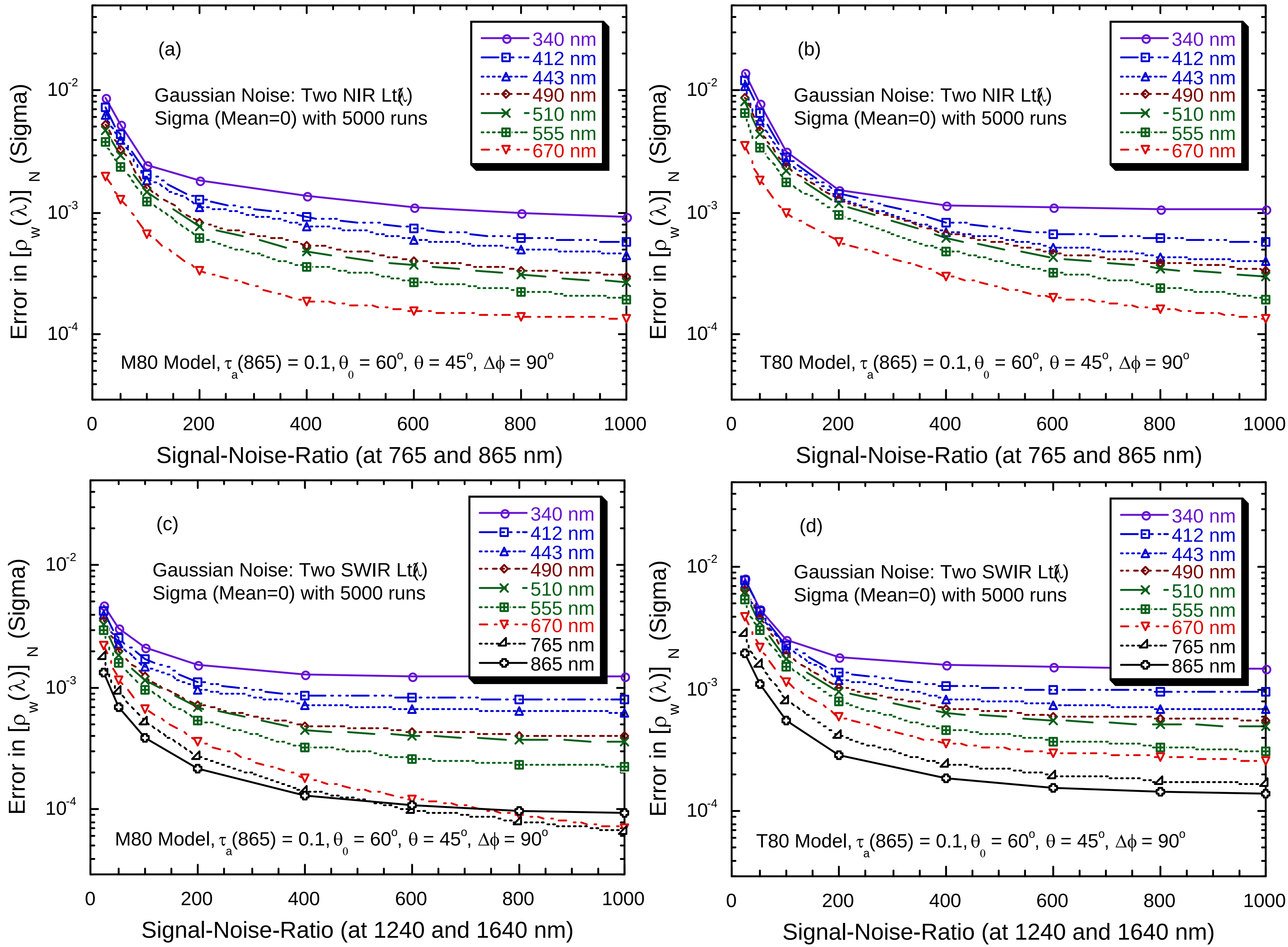
Field: 6 mg/m^3
w/o SWIR: 8 mg/m^3
w/ SWIR: 6 mg/m^3

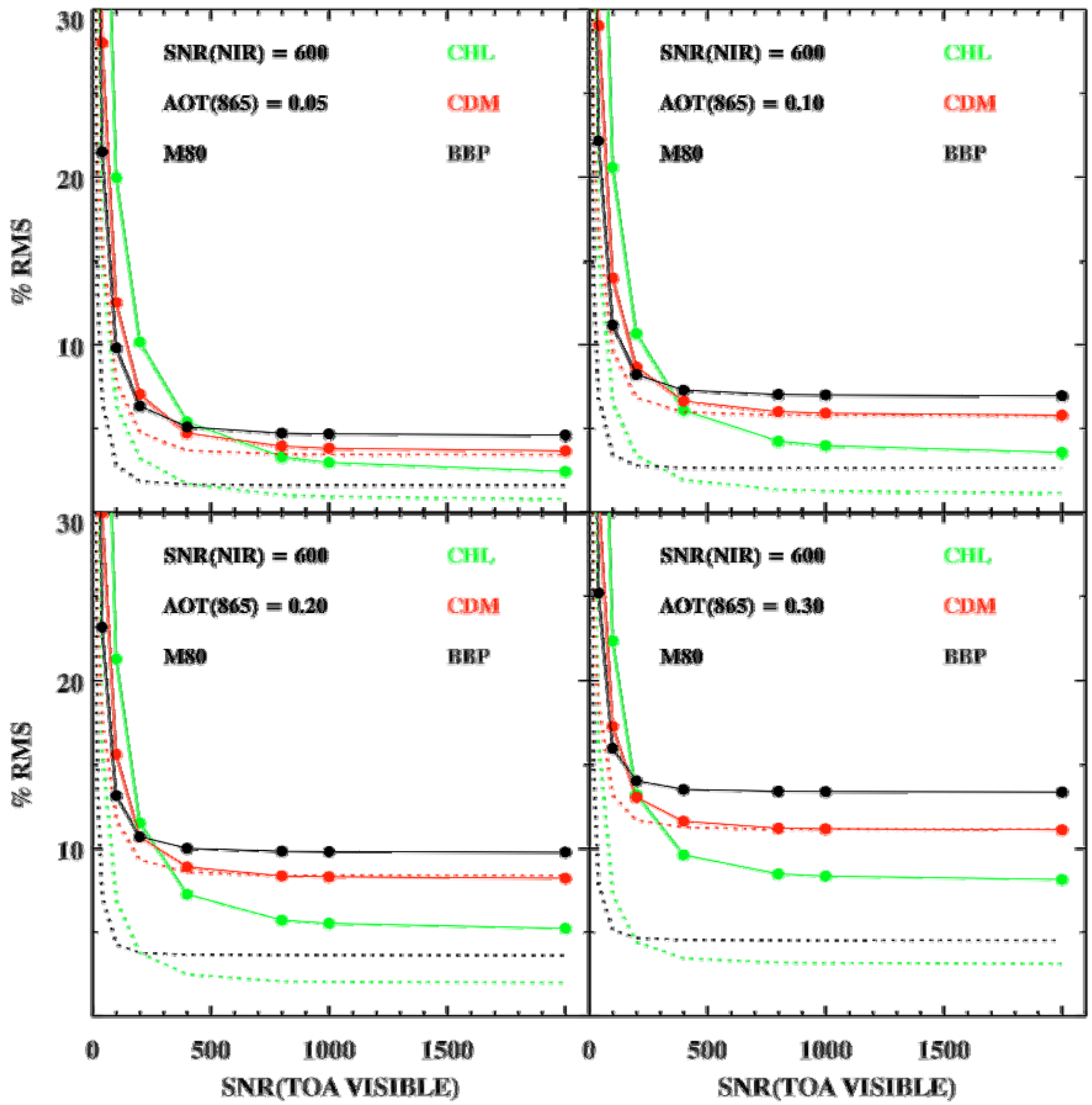




Chesapeake Bay

Unpublished, OBPG


(a)
Gaussian Noise: Two NIR Lt(λ)
Sigma (Mean=0) with 5000 runs
340 nm
412 nm
443 nm
490 nm
510 nm
555 nm
670 nm
M80 Model, τa(865) = 0.1, θ0 = 60°, θ = 45°, Δφ = 90°
Error in [ρw(λ)]N (Sigma)
Signal-Noise-Ratio (at 765 and 865 nm)
(b)
Gaussian Noise: Two NIR Lt(λ)
Sigma (Mean=0) with 5000 runs
T80 Model, τa(865) = 0.1, θ0 = 60°, θ = 45°, Δφ = 90°
Signal-Noise-Ratio (at 765 and 865 nm)
(c)
Gaussian Noise: Two SWIR Lt(λ)
Sigma (Mean=0) with 5000 runs
765 nm
865 nm
M80 Model, τa(865) = 0.1, θ0 = 60°, θ = 45°, Δφ = 90°
Signal-Noise-Ratio (at 1240 and 1640 nm)
(d)
Gaussian Noise: Two SWIR Lt(λ)
Sigma (Mean=0) with 5000 runs
T80 Model, τa(865) = 0.1, θ0 = 60°, θ = 45°, Δφ = 90°
Signal-Noise-Ratio (at 1240 and 1640 nm)



Average ocean retrieval AOT ~ 0.1, so an SNR ~ 1000 in the visible is an adequate minimum requirement. Fluorescence bands need a higher SNR.

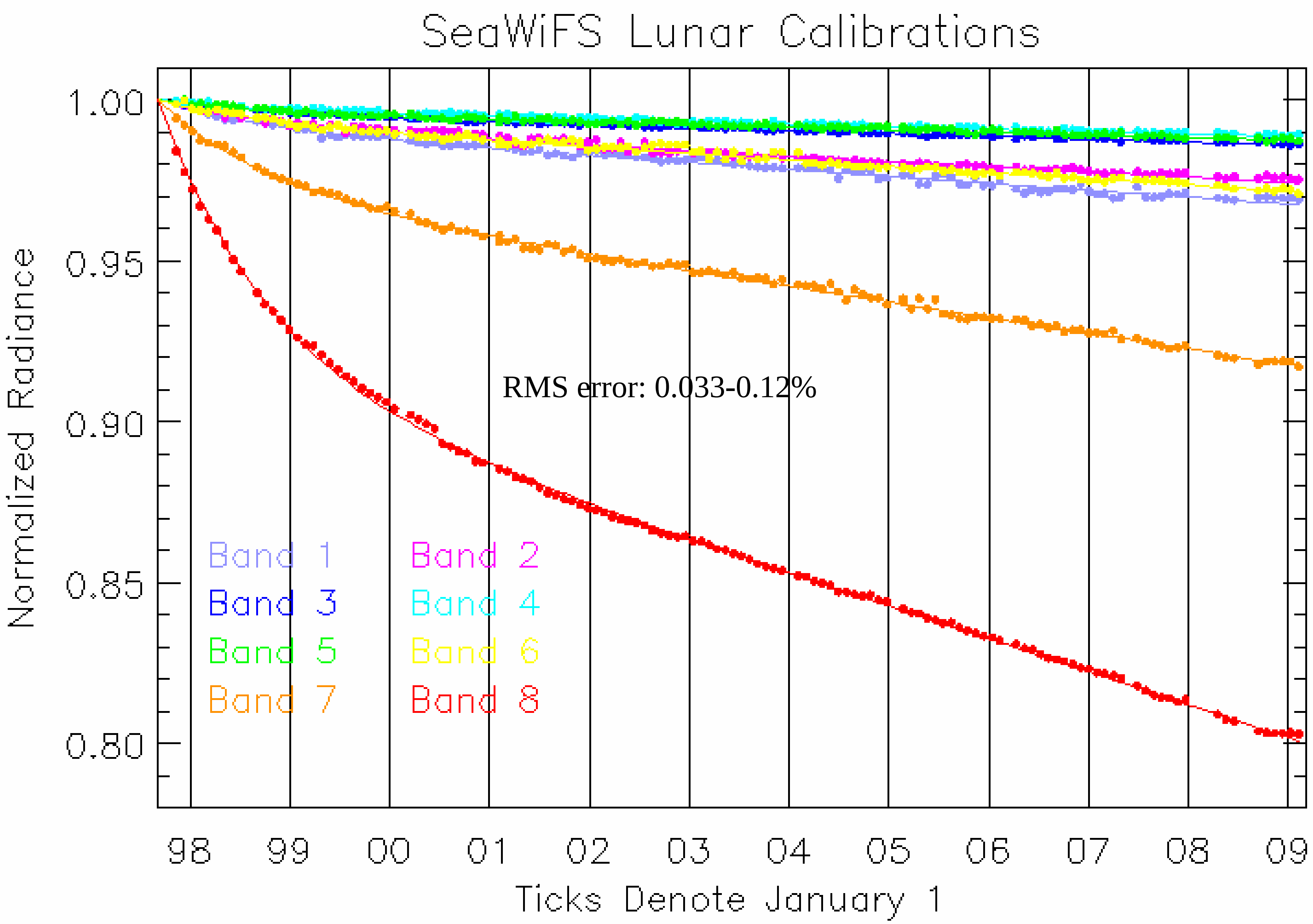
ACE Ocean Ecosystem Radiometer Minimum Requirements

- 5 nm resolution 350 to 775 nm (functional group derivative analyses)
- 300 – 1000:1 SNR aggregate bands UV & visible
  - 300:1 for 350 nm @ Ltyp
  - 1000:1 for bands between 360- 710 nm @ Ltyps
  - 1400:1 SNR for 678 @ Ltyp (chlorophyll fluorescence band)
- 10 to 40 nm bandwidth aerosol correction bands at 748, 765, 820, 865, 1245, 1640, 2135 nm
  - 600:1 SNR for 748, 765, 820 & 865 nm @ Ltyps
  - 250:1 SNR at 1245 nm and 1640 nm, 100 SNR at 2135 @ Ltyps
- Stability
  - 0.1% radiometric stability knowledge (mission duration)
  - 0.1% radiometric stability (1 month prelaunch verification)
- 58.3^o cross track scanning
- Sensor tilt ($\pm$20^o) for glint avoidance
- Polarization: < 1.0% sensor radiometric sensitivity,
  < 0.2% prelaunch characterization accuracy
- < 2% prelaunch radiance calibration accuracy (minimum)
  - Goal: 0.5% prelaunch calibration accuracy
- 1 km spatial resolution @ nadir
- No saturation in UV to NIR bands
- 5 year minimum design lifetime

ACE OES Multispectral Bands

λ	∇λ	Ltyp	Lmax	SNR-spec
350	15	7.46	35.6	300
360	15	7.22	37.6	1000
385	15	6.11	38.1	1000
412	15	7.86	60.2	1000
425	15	6.95	58.5	1000
443	15	7.02	66.4	1000
460	15	6.83	72.4	1000
475	15	6.19	72.2	1000
490	15	5.31	68.6	1000
510	15	4.58	66.3	1000
532	15	3.92	65.1	1000
555	15	3.39	64.3	1000
583	15	2.81	62.4	1000
617	15	2.19	58.2	1000
640	10	1.90	56.4	1000
655	15	1.67	53.5	1000
665	10	1.60	53.6	1000
678	10	1.45	51.9	1400
710	15	1.19	48.9	1000
748	10	0.93	44.7	600
765	40	0.83	43.0	600
820	15	0.59	39.3	600
865	40	0.45	33.3	600
1245	20	0.088	15.8	250
1640	40	0.029	8.2	250
2135	50	0.008	2.2	100

On-Orbit Sensor Stability Traceability



Other Requirements

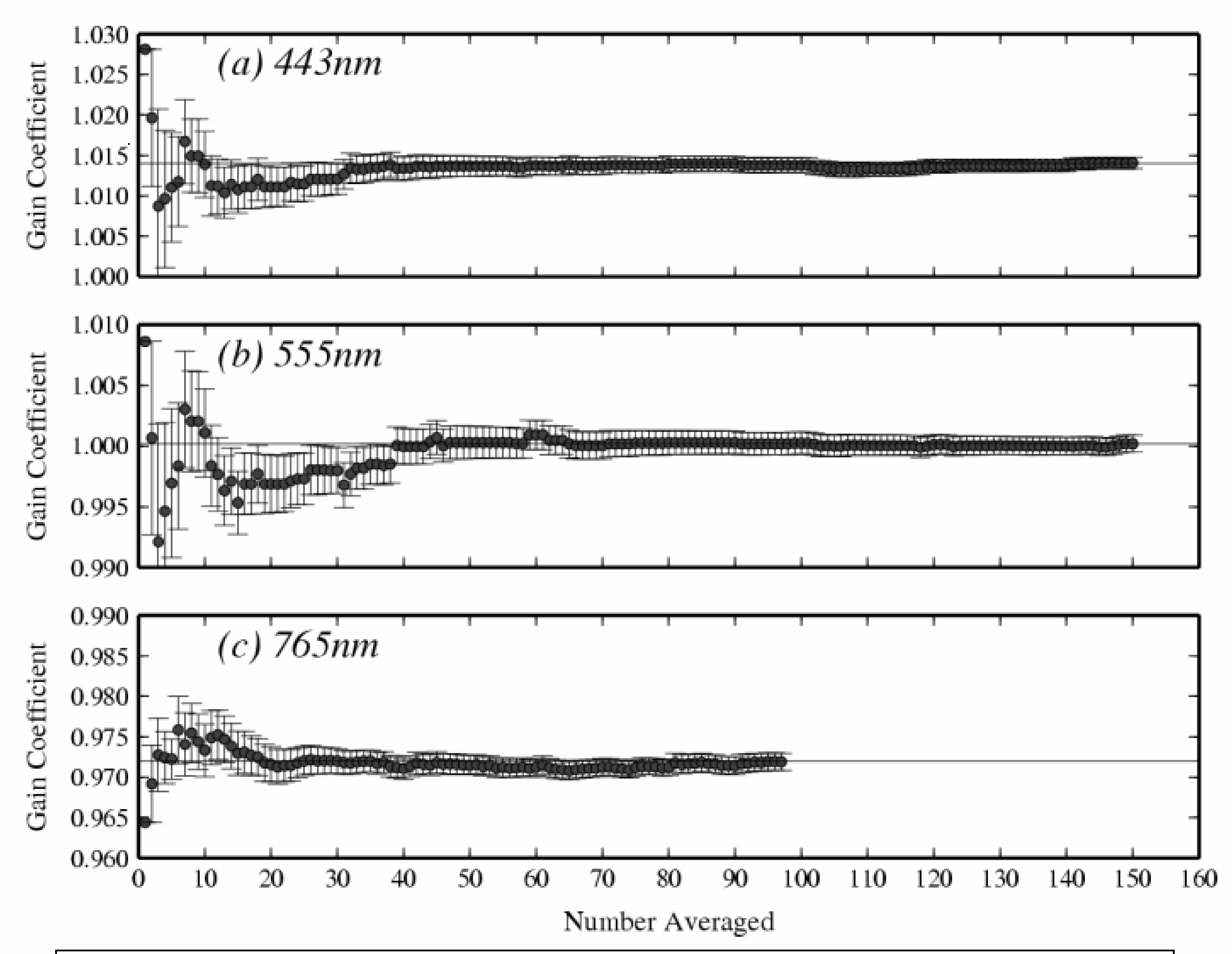
Global data sets from missions, models, or field observations

- **Measurement requirements** (satellite data processing)
  - Ozone concentrations
  - Total water vapor
  - Surface wind velocity
  - Surface barometric pressure
  - NO_2 concentration
  - Vicarious calibration & validation data
  - Full prelaunch characterization
- **Science requirements**
  - Sea surface temperature (SST)
  - Sea surface height (SSH)
  - Photosynthetically available radiation (PAR)
  - UV observations
  - Mixed layer depths (MLD)
  - CO_2
  - pH
  - Ocean circulation fields
  - Aerosol deposition (nutrients)
  - Run-off loading in coastal zone

Vicarious Calibration Gain Convergence

•Only a small % of samples result in a MOBY-satellite "match-ups" for the vicarious calibration.

• For MODIS, took over 2 years to collect enough match-ups to derive gain corrections.



B. A.Franz, S. W. Bailey, P. J. Werdell, and C. R. McClain, "Sensor-independent approach to the vicarious calibration of satellite ocean color radiometry," Appl. Opt. 46, 5068-5082 (2007)

Platform Requirements

- Orbit permitting 2-day global coverage of ocean radiometer measurements
- Sun-synchronous orbit with crossing time between 10:30 a.m. & 1:30 p.m.
- Storage and download of full spectral and spatial data
- Monthly lunar calibration at 7^{o} phase angle through Earth observing port