(yet more) Inverting Bioluminescent Radiance

(and)

A Very Brief Look at the Spectral Dependence of Forward Modeled $T*f/Q=R_{rs}/[b_b/(b_b+a)]$

Two unrelated projects by

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DMC Ocean Optics 2004

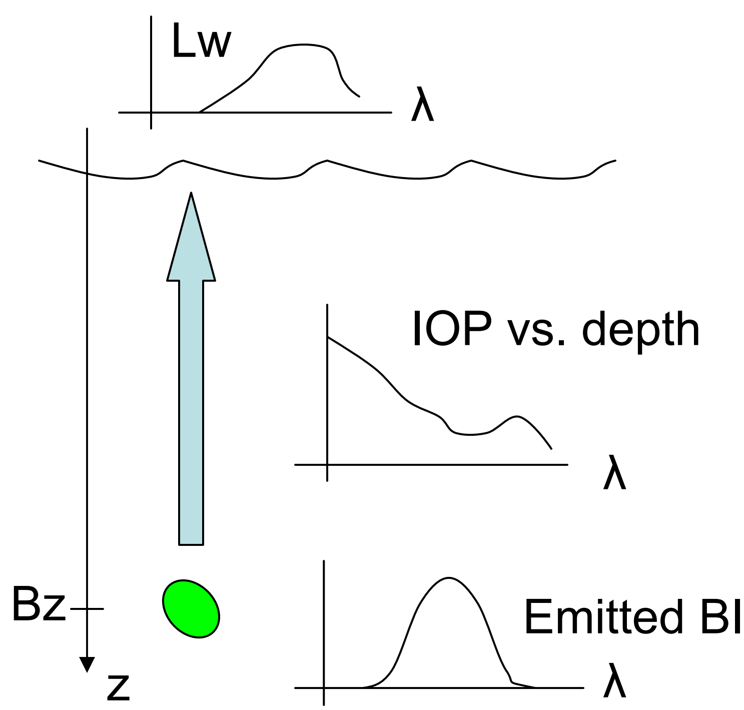
Part 1 – Bioluminescent Radiance Inversion

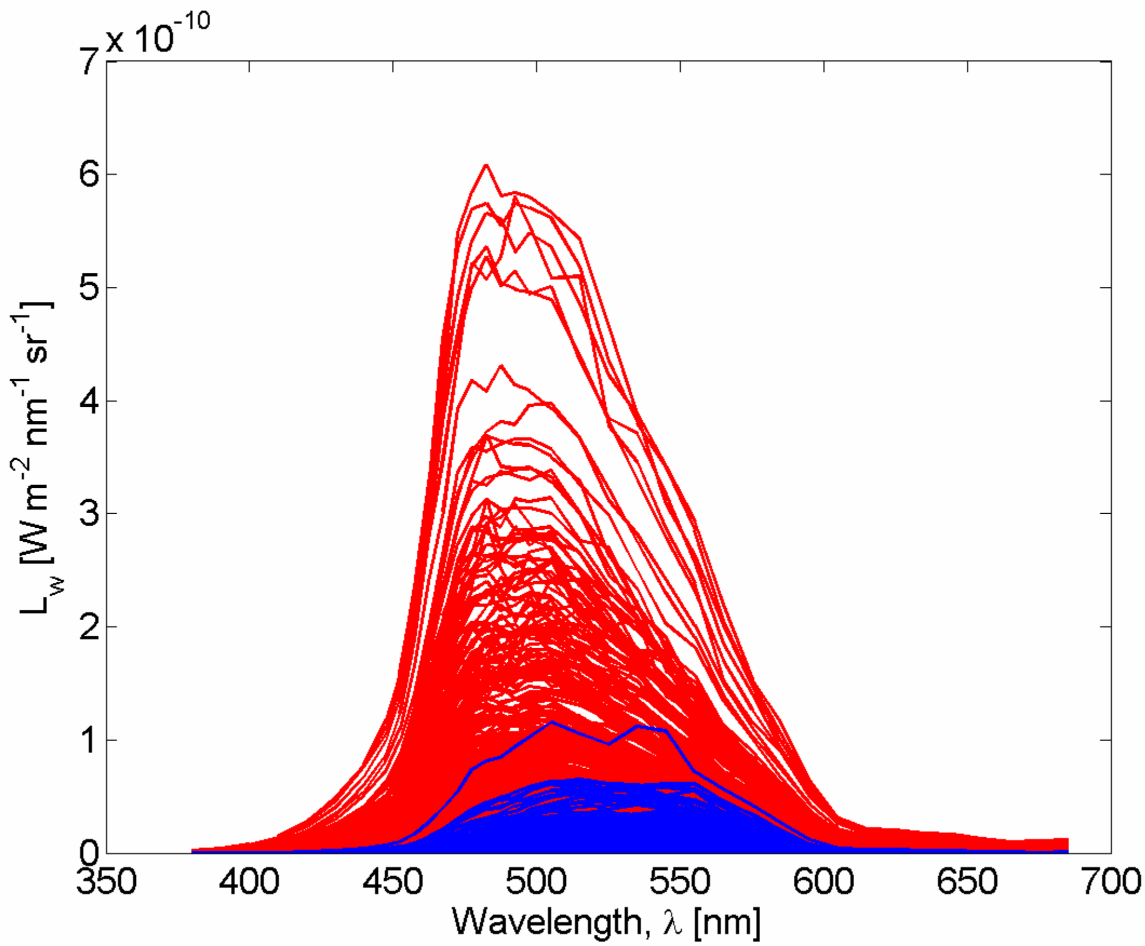
- Movement of objects in water stimulate bioluminescence within the water column
- Depth of stimulation dictates how far the light travels before reaching the surface
- Radiance that reaches the surface depends strongly on its absorption and scatter by water column IOP, as well as spectral shape and intensity of bioluminescence (i.e. how many phyto)

- Inverse Problem – can we use the bioluminescent radiance seen at the surface to determine the depth where the bioluminescence was stimulated?

Bioluminescent Radiance Inversion

- Dataset consists of ~7400 measurements of IOP vs. depth with bioluminescence measured (stimulated) at different depths from bathyphotometer and ac-9 [from the LEO-15 crew, see Matt Oliver]
- HYDROLIGHT was used to derive Lw from bioluminescent layer, propagated through water column IOPS and sea surface (no sun)





x 10^-10
7
6
5
4
3
2
1
0
L_w [W m^-2 nm^-1 sr^-1]
350
400
450
500
550
600
650
700
Wavelength, λ [nm]

Bradt (2004) derived a special (analytic) form of Conservation of Misery (a la Mobley)

$$\frac{N}{K} = F_B$$

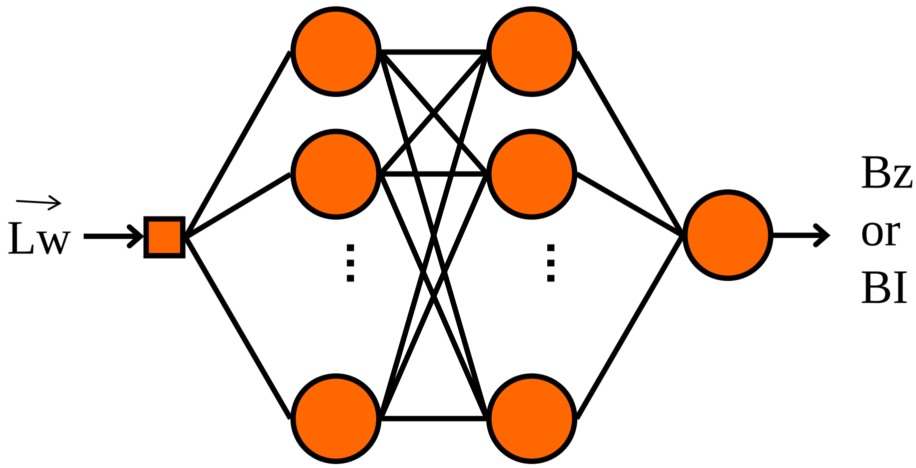
Furthermore, Bradt empirically related brute force to the elegance parameter

$$\frac{N}{K} = F_B = \eta \frac{1}{E}$$

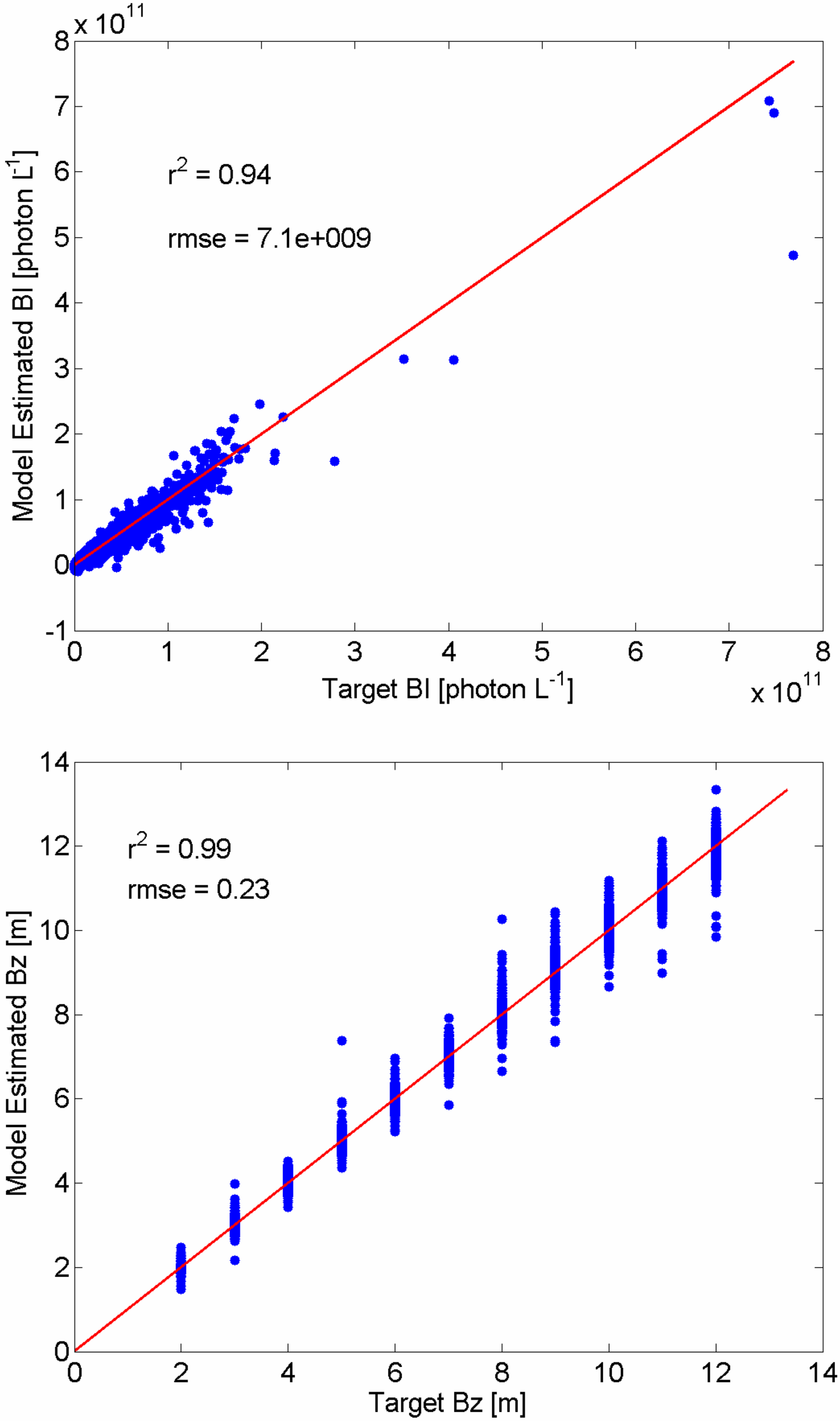
Application of Bradt's relationship to bioluminescent radiance

$$\lim_{k \to 0} \frac{N}{K} \qquad F_B \to \infty \qquad E \to 0$$

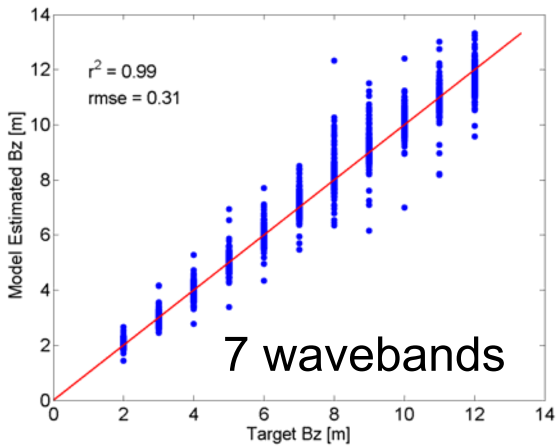
NN Inversion Model

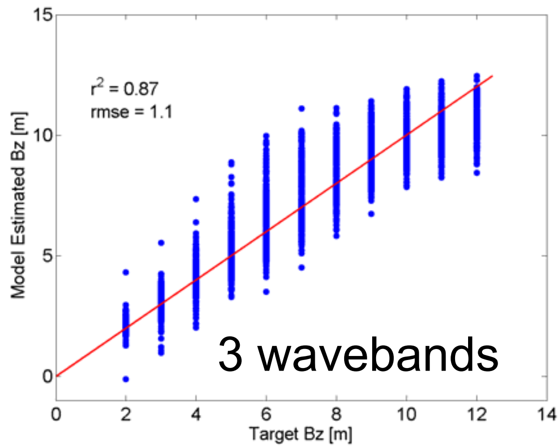


- Development of simple empirical model is tough since IOP, BI, and sea state are variable
- Two separate NN models were trained to estimate Bz and BI from spectral Lw
  - Network input Lw (~37 wavebands from 380-700)
  - Network output Bz or BI (depth or intensity)
- Generalization ability of network is very important!
  - Avoid too few or too many nodes (so that noise is not learned)
  - Stop network training early by monitoring performance on validation dataset
- NN models are tested on an independent dataset (60% used for training, 20% for validation, 20% testing)


x 10^11
r^2 = 0.94
rmse = 7.1e+009
Model Estimated BI [photon L^-1]
Target BI [photon L^-1]
x 10^11
r^2 = 0.99
rmse = 0.23
Model Estimated Bz [m]
Target Bz [m]

More NN Inversion





- NN model was able to extract information from hyperspectral data
- Trying wavelength subsets (every 5 wavebands and [400 480 550]) yielded degraded but reasonable results
- Empirical and analytic approaches seem particularly tough for this problem

- Analytic approach is preferable, but if the best you can do is empirical (i.e. band ratio), then consider a NN black box!

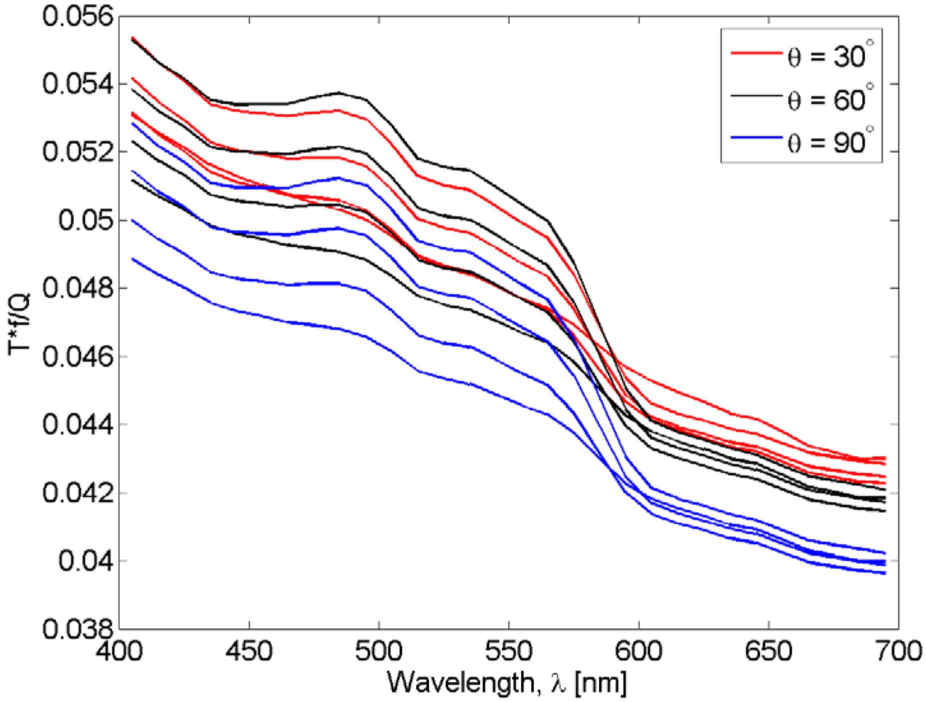
Part 2 – Forward Modeled Spectral Dependence of T*f/Q

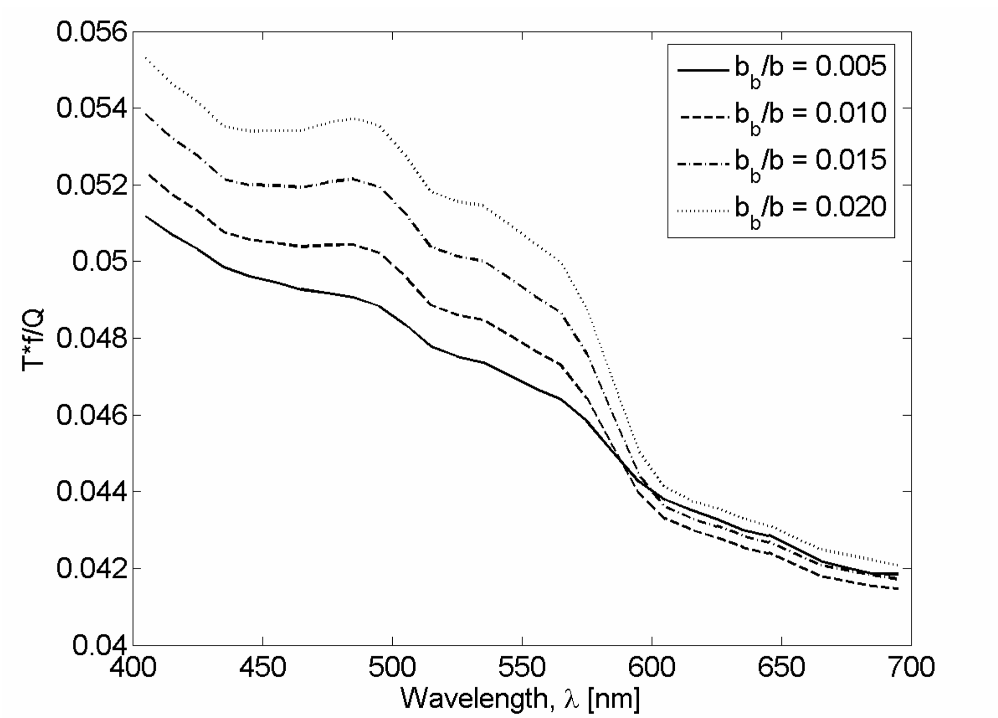
- Irradiance Reflectance is defined as R=Eu/Ed, and has been approximated (such as by Gordon et al.) as R=f*[bb/(bb+a)], with f~0.33 at z=0-
- f/Q depends on sun and satellite geometry as well as IOP
- Rrs=Lu/Ed, so define Q=Lu/Eu and include T~0.54 to propagate across sea surface

$$Rrs = T\frac{f}{Q}\left[\frac{bb}{bb+a}\right]$$

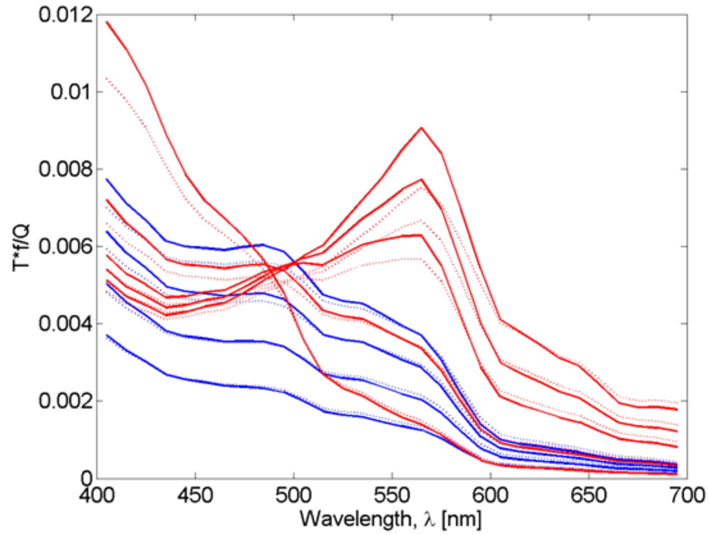
- T*f/Q can be an important parameter in Rrs inversion (typically assumed constant 0.051)
- Spectral dependence could influence spectral matching based algorithms

Forward Modeled Spectral Dependence of T*f/Q (HYDROLIGHT)





Finale



- Forward modeling shows T*f/Q has spectral variation, but assumption of spectrally flat T*f/Q=0.051 leads to 5-10% error in Rrs
- More accurate T*f/Q will probably become more important for inversion algorithms on calibrated hyperspectral data where we aim to retrieve more subtle features
- 20 forward HYDROLIGHT runs only taps the surface of this topic; next steps are to understand works of Morel and Gentili and others, serious HYDROLIGHT runs, and a good look at variation in the real world (i.e. Satlantic HyperPro can easily measure Q, combined with more sensors for bb,b)


Diffuse reflectance of oceanic waters. III. Implication of bidirectionality for the remote-sensing problem

André Morel and Bernard Gentili