Derivation of Inherent Optical Properties from Satellite Top of Atmosphere Measurements in Optically Complex Waters

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TOA EOF-Based Algorithms for IOPs

1. TOA Reflectance
2. EOF analysis
   - stepwise selection of EOF scores
3. Model to estimate IOPs/Chl
   - Multiple linear regression
   - Predictor variables: EOF scores
   - Response: IOPs, Chl

- Evolution of an approach developed for in situ data
- TOA approach initially developed on multispectral NOMAD satellite matchup dataset (Jeremy Werdell, GSFC)
1. Comprehensive characterisation of TOA EOF model using a synthetic dataset:

- TOA synthetic dataset has been constructed using coupled atmosphere-ocean model - Zhongping Lee & team
  - $\alpha_{ph}$ spectra collected from SEABASS
  - Other IOPs modelled using similar approach to IOCCG Report #5
  - Good representation of ‘real’ world measured IOPs

- Parameters varied: $\alpha_{ph}, \alpha_g, \alpha_d, b_{bph}, b_{bd},$ AOD ($\tau$), absorbing aerosols ($O_3, O_2, \text{water vapour}$), sza
Results

Model Scenarios

• EOF models derived from TOA $R_{rs}$ ($= L_t/(F_0 \cdot \cos \theta)$) and $R_{rs}$
  - $R_{rs}$ models permit comparison of model skill when atmospheric is present and absent in AOP spectra

• Two IOP examples:
  - $a_{ph}$ & $b_{b_{tot}}$ but models derived for all IOPs

• Models run for $\tau = 0.1, 0.3, 0.5, 0.8$

• Absorbing aerosols ($O_3, O_2, \text{water vapour}$) included
Results - $a_{ph}$ Models

$\tau = 0.1$  \hspace{1cm} $\tau = 0.3$  \hspace{1cm} $\tau = 0.5$  \hspace{1cm} $\tau = 0.8$

TOA $R_{rs}$

$\text{measured } a_{ph} \text{ (m}^{-1})$

$\text{modelled } a_{ph} \text{ (m}^{-1})$

$R_{rs}$

$\text{measured } a_{ph} \text{ (m}^{-1})$

$\text{modelled } a_{ph} \text{ (m}^{-1})$
Results - $\alpha_{ph}$ Model Skill Metrics

$c.f. \text{ model skill metrics used by Werdell et al. (2013), AO, 52(10), 2019.}$

\begin{align*}
\tau &= 0.1 \\
\tau &= 0.3 \\
\tau &= 0.5 \\
\tau &= 0.8
\end{align*}

\begin{align*}
\text{r}^2 &
\text{rmse} \\
\text{ratio} &
\text{MPD (\%)}
\end{align*}

wavelength (nm)
Results - $\alpha_{ph}$ Model Skill Metrics

$\tau = 0.1$  $\tau = 0.3$  $\tau = 0.5$  $\tau = 0.8$

c.f. model skill metrics used by Werdell et al. (2013), AO, 52(10), 2019.

Little difference between IOPs derived from TOA $R_{rs}$ and those from $R_{rs}$

rmse

ratio

MPD (%)
Results - $\alpha_{ph}$ Model Skill Metrics

$\tau = 0.1$  $\tau = 0.3$  $\tau = 0.5$  $\tau = 0.8$

c.f. model skill metrics used by Werdell et al. (2013), AO, 52(10), 2019.

$\tau$ has little effect on model skill

overestimate  underestimate

PACE Science Team Meeting 20-22 January 2016 - Beckman Institute, Caltech, CA
Results - $b_{b_{tot}}$ Models

$\tau = 0.1$  $\tau = 0.3$  $\tau = 0.5$  $\tau = 0.8$

TOA $R_{rs}$

$\tau = 0.8$

$\tau = 0.5$

$\tau = 0.3$

$\tau = 0.1$

$R_{rs}$

measured $b_{b_{tot}}$ (m$^{-1}$)

modelled $b_{b_{tot}}$ (m$^{-1}$)
Results - $b_{btot}$ Model Skill Metrics

$c.f.$ model skill metrics used by Werdell et al. (2013), AO, 52(10), 2019.

- $\tau = 0.1$
- $\tau = 0.3$
- $\tau = 0.5$
- $\tau = 0.8$

**Metric:**
- $r^2$
- rmse
- ratio
- MPD (%)
Approach performs well over a wide range of water constituent concentrations & AOD w/absorbing gases
Future Analyses

- Interrogate synthetic dataset to perform:
  - Sensitivity analyses
  - Investigation of optimal methods to train & implement model - global, regional, water type, ...
  - Development of operational methodology
What we said we’d do...

2. Model development and assessment using HICO & CASI datasets:

- HICO and aircraft imagery with corresponding validation data currently being collated (Dave Miller, NRL DC)

HICO imagery of Bedford Basin, NS, Canada

= Bedford Basin
Summary

• Tests of the approach on both real (NOMAD) and synthetic datasets (Lee) show high potential for circumventing conventional AC

• IOPs retrieved with accuracy comparable (or better) than published methods

• Good candidate for coastal/inland waters where AC is challenging

• On orbit sensor characterisation: EOF modes may reveal sensor drift over time