Challenges of System Vicarious Calibration for non-standard atmospheric correction

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Long-term global EO archive of Ocean Colour ECV: $\rho_w$, chl, IOP

Phase 2 started in February 2014: continuous update of data products following review of climate researchers + extension to new sensors

Past and in-flight sensors currently considered: SeaWiFS, MODIS, MERIS, VIIRS. OLCI planned for 2016

Two types of atmospheric corrections (AC) considered:

- "Standard/historical AC", e.g. NASA-l2gen
  \[ \rho_w(\lambda_{VIS}) = \rho_{gc}(\lambda_{VIS}) - \rho_{atm}(\lambda_{NIR}) \]
  \[ t_d(\lambda_{NIR}) \]

- "Non standard AC", based on a marine model and full spectrum inversion
  e.g. HYGEOS-POLYMER, HZG-NN, FUB-SIACS
  \[ \rho_w(\lambda_{VIS}) = \rho_{gc}(\lambda_{VIS}) - \rho_{atm}(\lambda_{NIR}) \]
  \[ t_d(\lambda_{NIR}) \]

System Vicarious Calibration (SVC): post-launch mean to harmonise OC radiometry across all missions
What does SVC tell us?

SVC formalism considers \{sensor+algorithms\} as a whole and is thus a very pragmatic way to:

- Specify requirements on L1 radiometry (system input) by requirements on $\rho_w$ (system output)
- Detect (or at least validate) any sensor drift at $\rho_w$ level, through analysis of long-term time series

Most generic formulation of the SVC problem, for a given algorithm, observation and reference is:

With $\rho_w = F(\rho_{TOA})$, find $g$ such that $F(g \ast \rho_{TOA}) = \rho_{w,REF}$ for all bands

$\textbf{SVC} = \text{sensitivity to TOA} = \text{assessing how much do we need to (vicariously) calibrate}$

**l2gen**

Band per band calibration

Sensitivity in $1/t(\lambda)$

Need a SVC further to instrument calibration

**POLYMER**

Coupled calibration

Non-intuitive sensitivity

Need for SVC – but maybe different calibration requirements?
Specificity of spectral matching AC

By construction POLYMER inversion is invariant to any calibration following

\[ g(\lambda) = 1 + \frac{c_0 T_0(\lambda) + c_1 \lambda^{-1} + c_2 \lambda^{-1}}{\rho_{GC}(\lambda)} \]

- Totally different gains
- Very same \( \rho_w \) and validation plots
Feasibility of SVC?

The strict SVC problem cannot be solved, unless there exists IOPs such that $\rho_w^{\text{REF}}(\lambda) = \rho_w^{\text{MOD}}(\lambda, \text{IOPs})$ for all $\lambda$.

The best we can do is a SVC in a least-square sense:

With $\rho_w = F(\rho_{\text{TOA}})$, find $g$ to minimise $\| F(g \ast \rho_{\text{TOA}}) - \rho_w^{\text{REF}} \|$

**Standard AC**

- Gains always exist
- Gains are unique after NIR calibration
- Gains can be computed explicitly at each band
- Gains yield to a perfect match with reference data, at all bands

**Spectral matching (POLYMER)**

- “True” gains exist only if $\rho_w^{\text{MOD}}$ fit reference data
- Infinity of gains are possible
- Gains are computed by a non-linear spectrally coupled system
- Gains only yield to an approximate match with reference data, in a least-square sense. Errors vary with bands

MODIS validation at MOBY after optimal pixel-by-pixel recalibration
Findings from POLYMER SVC at MOBY

SVC gains have no meaning per se, but comparison between two algorithms can provide information.

**SeaWiFS**

- **412 nm**
  - L2gen assumption in farthest NIR band retrieved by POLYMER
  - Excellent robustness

- **490 nm**
  - Such correction @412 not detected by POLYMER

**MODIS**

- **412 nm**
  - L2gen assumption in farthest NIR band retrieved by POLYMER
  - Excellent robustness

- **488 nm**
  - Temporal degradation after 2013?
Conclusion

- Spectral matching ACs are more and more used by the OC community, cf. OC-CCI
- Such algorithms ask new questions in term of calibration requirements (interband vs absolute)
- System Vicarious Calibration can bring answers but needs a new perspective:
  - Link between TOA and BOA does not follow classical OC formulation – cf. Jacobian matrix
  - Gains are spectrally coupled and cannot be computed by the standard method
  - Gains are not always unique
  - The strict SVC problem is not solvable → define SVC in a least square sense
- SVC of spectral matching AC remains meaningful and useful to bring an extended number of data

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