Bio-optical characterization of the water masses off the Svalbard Islands by laser-induced fluorescence

Part 2


Laser Applications Section, ENEA, Italy

4th EARSel Workshop on Remote Sensing of the Coastal Zone

4th Workshop Remote Sensing of the Coastal Zone
Coasts and Climate Conflicts
Chania (Crete), Greece
## AREX Oceanographic transects

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AREX 2006 - Results

Bio-optical Characterization of the water masses
AREX 2007 - Results
AREX 2006 – Transect V

Carotenoids

Phycocyanin

Phycoerythrin
Comparison with oceanographic data

- The trend of the average variables as a function of latitude already shows some correlations and anticorrelations.

Inverse proportionality between CDOM and salinity that characterizes other oceanic provinces seems not been observed everywhere (irregularity and dynamicity of the polar environment).
Comparison with oceanographic data

- Anticorrelation behavior is observed along the water column in selected stations, where from the batimetry analysis, the occurrence of superficial, intermediate and deep waters are monitored.
Anticorrelation behavior is observed also along the water column where from the batimetry analysis, the occurrence of superficial waters are monitored.
Phycobilin pigments, as phycoerythrin and phycocyanin accessory algal pigments, have been observed in the northern area, close to the northern Spitsbergen coastline, during AREX 2006 and in the southern area, during AREX 2007. The occurrence of these fluorescent pigment is the indication of Cryptophyceae Cyanophyceae and Rhodophyceae algae in the natural phytoplanktonic community.
**Tyrosine and Tryptophan protein-like fluorescence**

- The effect of a strong *biological activity* in superficial waters is clearly evident from the maps, with a strong correlation between *tyrosine* and *biomass* production.
NADPH and carotenoids pigments

- These components are chemotaxonomic biomarkers of the phytoplanktonic biomass distribution, but their different spatial distribution is due to changes in radiance and seawater currents. In comparison with biomass distribution, Carotenoids shows overlapping areas in the central and northern seawaters of the Spitsbergen region, but a different behavior in the southern Atlantic section, thus supporting the hypothesis of a different primary productivity of the investigated environments.
Principal component analysis (PCA) has been applied on the overall dataset collected by CASPER during AREX 2006 (328 stations * 4 spectra = 1312 spectra). PCA can actually be used as a way to better analyze large amount of data, especially in those situations where a strong correlation among measurements on the samples is expected. Actually, it is necessary to address at least the following fundamental problems, namely:

- How many spectral bands are needed to completely describe each spectrum collected by CASPER?
- is there any possible way to classify different waters (coastal, oligotrophic oceanic, deep and surface waters, etc.) by means of an automated procedure?
- can the acquisition be simplified in order to use data correlation (and/or data redundancy) to reduce the number of acquired spectra?

PCA has been applied to: 1) the entire dataset; 2) euphotic (up to 100 m depth); 3) deep waters (> 100m). Different ways to reduce the spectral resolution have been investigated (binning at 5, 10, 25, 50 and 100 nm) and the optimal compromise was reached for bins of 25 nm.
The PCA is a statistical analysis aimed to give a simplified view of very large data sets, especially those characterized by a high number of measurements per item and with an high correlation degree among different measurements. Main objective of PCA is to seek for that special combination of the input variables (called Principal Components) for which the highest variance is retained by the minimum number of components.

PCA looks for new variables given as linear combination of the input ones, with the purpose of retaining as much as possible of the variance contained in the original measurement. The search is made with the goal of loosing nothing of the original information, and at the same time by reducing as much as possible the dimensionality of the new variables.
PCA - Complete AREX 2006 dataset

PC1 closely resemble a spectrum obtained by a simple average of the spectra contained in the entire data set. Since PC1 is able to explain a noticeable amount of the variance (more than 60%), therefore we may conclude that the total signal output from the spectrometer roughly indicates the water type.

It is to be expected that oligotrophic waters are associated with relatively high Raman signal and low fluorescence from CDOM excited at 405 nm and CDOM excited at 266 nm. The contribution from UV_F water sample spectra appears of little significance.

PC1 correspond to Raman and to the total LIF signal.
PC2 is characterized by a relatively intense peak attributed to CDOM emitted at 415 nm. Indeed it contributes differently in singly and doubly filtered water. As noted also for PC1 the contribution from UV_F appears of little significance.

PC2 corresponds to CDOM contribution.
**PCA - Complete AREX 2006 dataset**

**PC3** is dominated by the Raman emissions at around 290 and 450 nm and the contribution from the Chl-a fluorescence at 680 nm starts to gain importance. Although PC3 accounts for less than 10% of the overall spectra variance, it has an important meaning from the point of view of *water classification*, because it contains the contribution from *algae*, a relevant water constituent, and then it is expected it will play a significant role for the water type discrimination.

**PC4** gives a variance 5%, it appears dominated by an approximately equal contribution from CDOM excited at 405 nm and Chl-a with respect to the Raman emission.
PCA - Complete AREX 2006 dataset

Scores, are represented in two dimensional plots reporting the ratings data, projected onto two consecutive principal components (note that the scores computed by PCA have zero mean)

- PC1 and PC2 anticorrelate;
- the points corresponding to the same transect tend to form clusters due to the smooth and persistent change in the optical characteristics.

Conclusion: an increase of the total LIF signal (PC1) corresponds to a decrease in the principal components dominated by fluorescence from CDOM thus giving the base for establishing a negative correlation between water transparency and dissolved matter content.
PCA - Complete AREX 2006 dataset

• PC1 and PC2 anticorrelate

Suspicious!

Water sampled at increasing latitudes is characterized by an increase in the component PC2, i.e. by an increase of the CDOM content.
The superficial waters dataset takes into account only seawater sampled at depths not below 100 m.

PC1 represents again an average spectrum.

PC2 is no more dominated by the 400 nm peak due to CDOM in the UV_FF spectrum, while it shows contributions from Raman and protein-like fluorescence.

PC3 strong Chl contribution.
The first and the second components are no more anticorrelated;
Data points corresponding to the same transect tend to form clusters.

Clustering indicates that regional characteristics can be used to discriminate water masses. In general, it can be noticed that coastal and offshore waters are almost uniformly scattered along the PC1 and oceanic waters (H, K, O) tend to have high PC2 values, i.e. dominated by protein-like substances.
More scattered data with coastal water samples concentrated significantly on high values of PC3. A possible explanation of this behavior is that coastal waters (S, EB) are characterized by an increase of both Chl-a and CDOM which have approximately the same weight in PC3.
PCA - Deep waters dataset

- The deep waters dataset takes into account only seawater sampled at depths below 100 m

Principal components of deep waters have coefficients quite similar to those obtained for waters of all depths. For the deep waters dataset, PC1 is able to explain about 52% of the variance, dominated by Raman and CDOM also in PC2. PC4 the contribution on the spectrum given by the Chl-a has now almost completely disappeared.
PCA - Deep waters dataset

- The anticorrelation already noticed in complete dataset is now much more **evident**;
- data points corresponding to the same transect tend to form **clusters**
- data scattering is strongly **reduced** because the points that tend to occur apart from the line individuated by the bottom of the cluster towards higher values of PC2 have now disappeared.

Can be observed a increase of PC1 and a decrease of PC2 while samples go toward clearer waters

Clusters more defined due to more homogeneous water samples, less influenced by remnants due to biological life
The large database of fluorescence spectra showed the advantage of being a suitable tool for superficial and depth distribution analysis. Moreover, they can be used also as input for a refined and complete statistical analysis, that supplied robust information on the different waters monitored during the campaigns.

• How many spectral bands are needed to completely describe each spectrum collected by CASPER? 7 - 8
• Is there any possible way to classify different waters (coastal, oligotrophic oceanic, deep and surface waters, etc.) by means of an automated procedure? Yes
• Can the acquisition be simplified in order to use data correlation (data redundancy) to reduce the number of acquired spectra? Yes
Finally The end!

- Thank you all for your attention! Hoping not to be bored
- I’m ready for your questions…