N97 Estimated the Bio-optical Indicators in the Sea of Azov in 2013–2014 by Using the Simulation Results and Ocean Color imagery

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Aim of the Study

- identify bio-optical indicators *index*34 and $b_{bp}(555)$ from *MODIS L2* products within the investigated areas
- assimilate the ocean-related products in the 3-D model at the surface layer and the deep sea
- filling the gaps arising due to satellite imagery unavailability and/or cloud covering by the simulation results
- obtaining continuous in time and space information about bio-optical indicators in the Sea of Azov

Study Area and Data Sources

- information on remote-sensing reflectance with central wavelengths of bands 438, 531 nm, particulate backscattering coefficient at 555 nm and diffuse attenuation coefficient for downwelling irradiance at 490 nm during the 2013-2014 in daily resolution
- simulation hydrodynamic fields based on a *Princeton Ocean Model* over a domain with 1 km resolution, vertically discretized into 11 terrain-following sigma levels
- atmospheric forcing data from provided hourly with 0.1° horizontal resolution by the *SKIRON* model run by the Atmospheric Modeling and Weather Forecasting Group, Greece (*http://forecast.uoa.gr*)

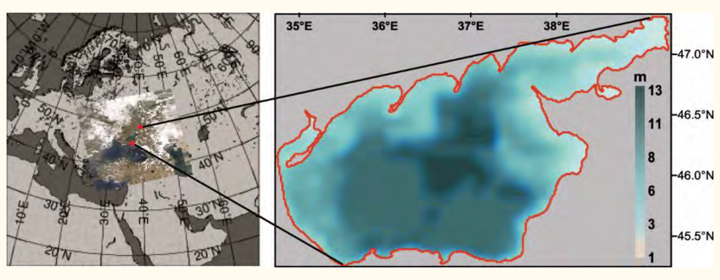
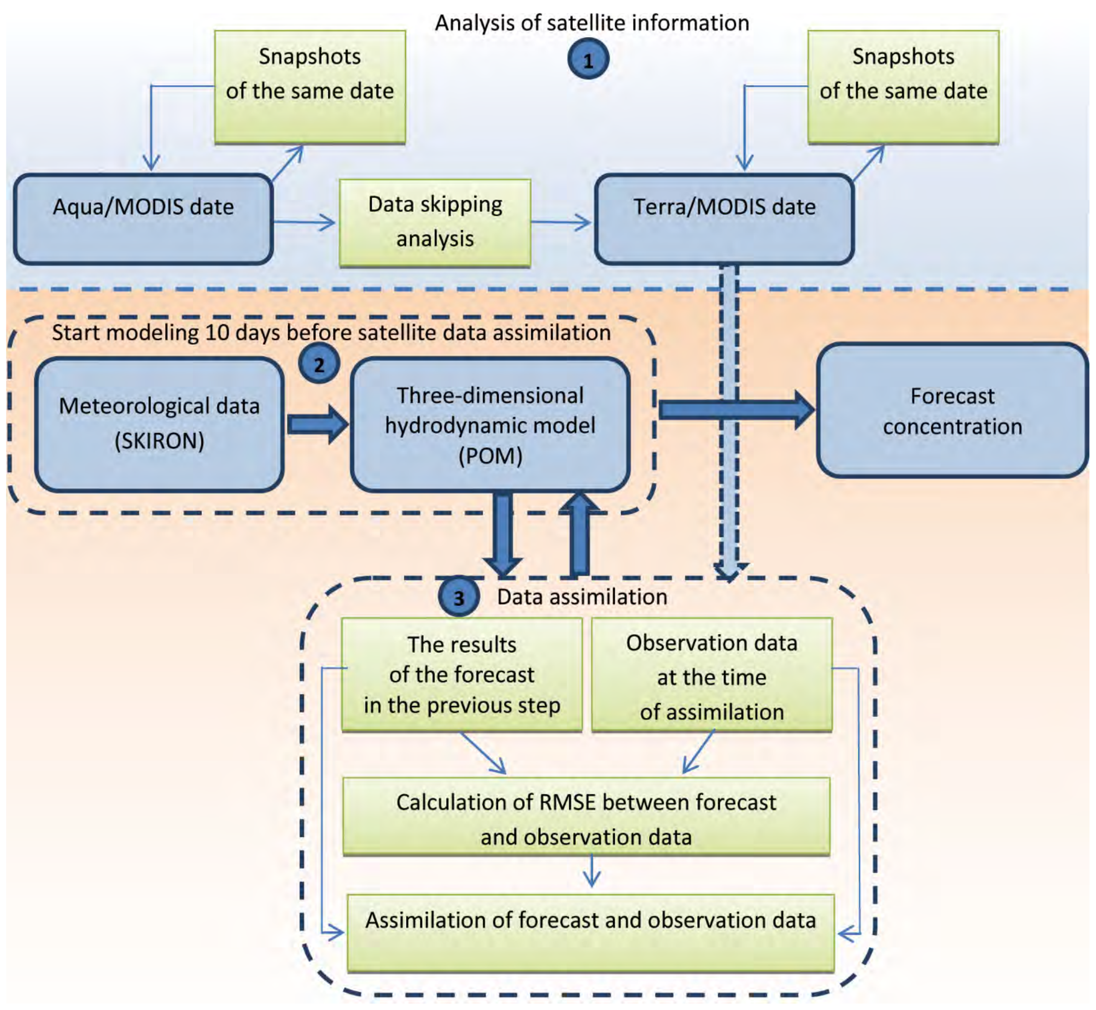


Fig.1. Setting within Europe study area Azov Sea basin from Ocean Color web site (left) and his topographic bathymetry map (right)

Methodology



Methods and Procedure Assimilation

Equations of bio-optical indexes [1]

***index* 34** = $L_{WN}(531)/L_{WN}(488)$

were $R_{RS}(531) = L_{WN}(531)/Fo(531)$ and $R_{RS}(488) = L_{WN}(488)/Fo(488)$

Fo – extraterrestrial solar irradiance [2]; *λ – wavelength*, $L_{WN}(\lambda)$ – normalized water-leaving radiances; $R_{RS}(\lambda)$ – remote-sensing reflectance at 531 and 488 nm

$\mathbf{b_{bp}(555)} = \{6{,}76L_{WN}(555)+0{,}03[L_{WN}(555)]^3 + +3.4L_{WN}(555)[I_{510}]^{3.8} - 0.84\}10^{-3}$

were $\mathbf{I_{510}} = L_{WN}(555)/L_{WN}(510)$, $R_{RS}(555) = L_{WN}(555)/Fo(555)$, $R_{RS}(510) = L_{WN}(510)/Fo(510)$

The successive recursive algorithm of data assimilation, based on **Kalman** theory of optimal filtration [3]

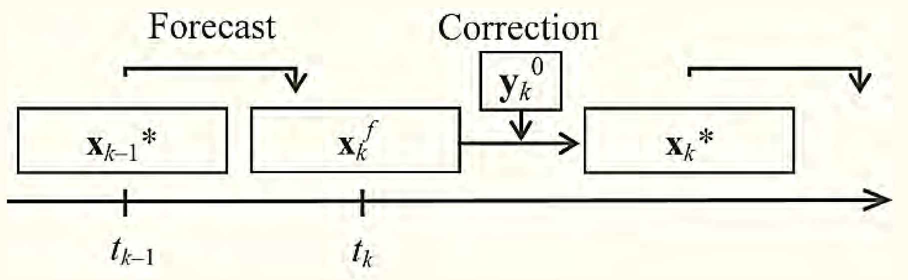


Fig.2. The scheme of the algorithm of assimilation

$$\mathbf{x^f_k} = \mathbf{A}(x^*_{k-1}) + \xi_k \qquad (1)$$

$x^f = (x^f_1, x^f_2,..., x^f_n)$ are calculated based on the value found of vector $x^* = (x^*_1,x^*_2,...,x^*_n)$, $x^* \in R^{1\times n}$

k – assimilation step; A – model statement; x^*_{k-1} – vector of the measurements analyzed at the time point t_{k-1} (the estimate obtained at (k−1) time point); $\xi \in R^{1\times n}$ – random vector of the model errors. Satellite observational data construct vector $y^0 = (y^0_1, y^0_2,..., y^0_m)$, $y^0 \in R^{1\times m}$

$$\mathbf{y^0_k} = \mathbf{B}_k(y^{0*}_k) + \zeta_{kk} \qquad (2)$$

$\mathbf{B}_k \in R^{m\times n}$ – is projection matrix of the model space into the space of dimension observations

$y^{0*}_k \in R^{1\times m}$ – observations vector at a time point t_k; ζ_k – vector of observation errors. System noise (1) and measurement noise (2) are Gaussian random processes with zero expected value. Optimal estimate of concentration is calculated on the basis filtration algorithm

$$\mathbf{x^*_k} = x^f_k + \mathbf{K}_k(y^0_k - \mathbf{B}_k(x^f_k)), \quad \mathbf{K}_k = \mathbf{P}_k\mathbf{B}^T_k(\mathbf{B}_k\mathbf{P}_{k-1}\mathbf{B}^T_k + \mathbf{R}_k)^{-1}$$

x^f_k – model concentration forecast; $\mathbf{K}_k \in R^{m\times n}$ – unidentified Kalman gain; $\mathbf{P}_k \in R^{m\times n}$ covariance matrix of forecast errors; $\mathbf{R}_k \in R^{m\times n}$ – covariance matrix of observation and model errors.

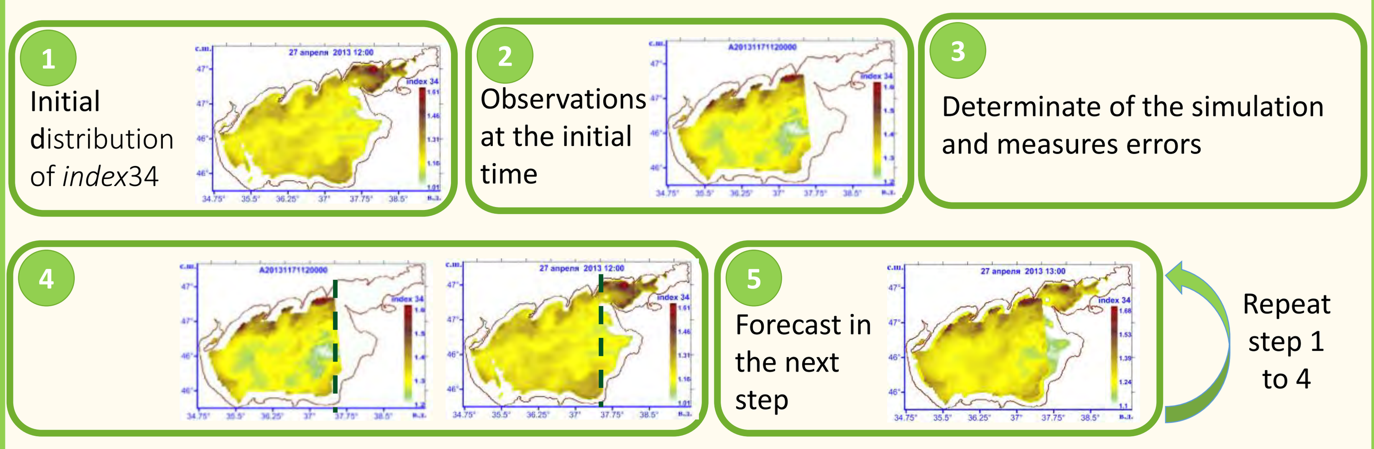
Quality criteria:

Root square error $\sqrt{\sum_{i=1}^{N}(X_{predicted\,i} - X_{observed\,i})^2/N}$

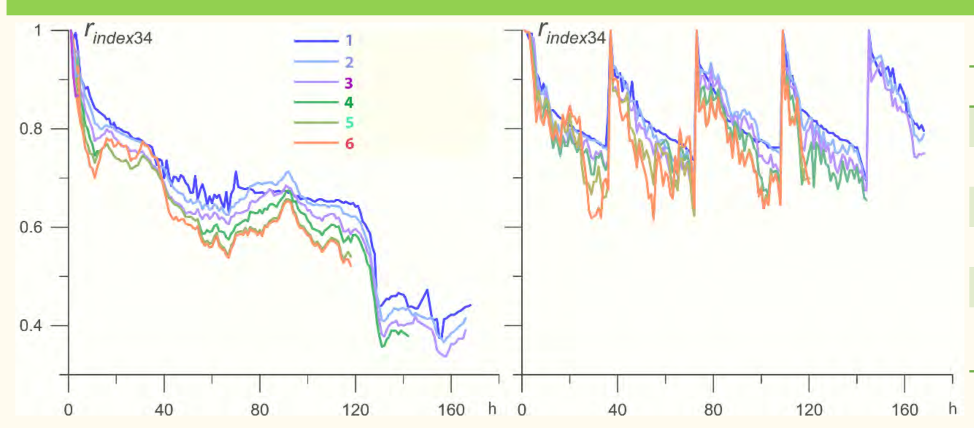
Mean absolute error $1 - \dfrac{\sum_{i=1}^{N}(X_{predicted\,i} - X_{observed\,i})^2}{\sum_{i=1}^{N}(|X_{predicted\,i} - \bar{X}_{observed\,i}| + |X_{observed\,i} - \bar{X}_{observed\,i}|)^2}$

Index of agreement $\sqrt{\sum_{i=1}^{N}|X_{predicted\,i} - X_{observed\,i}|/N}$

Results

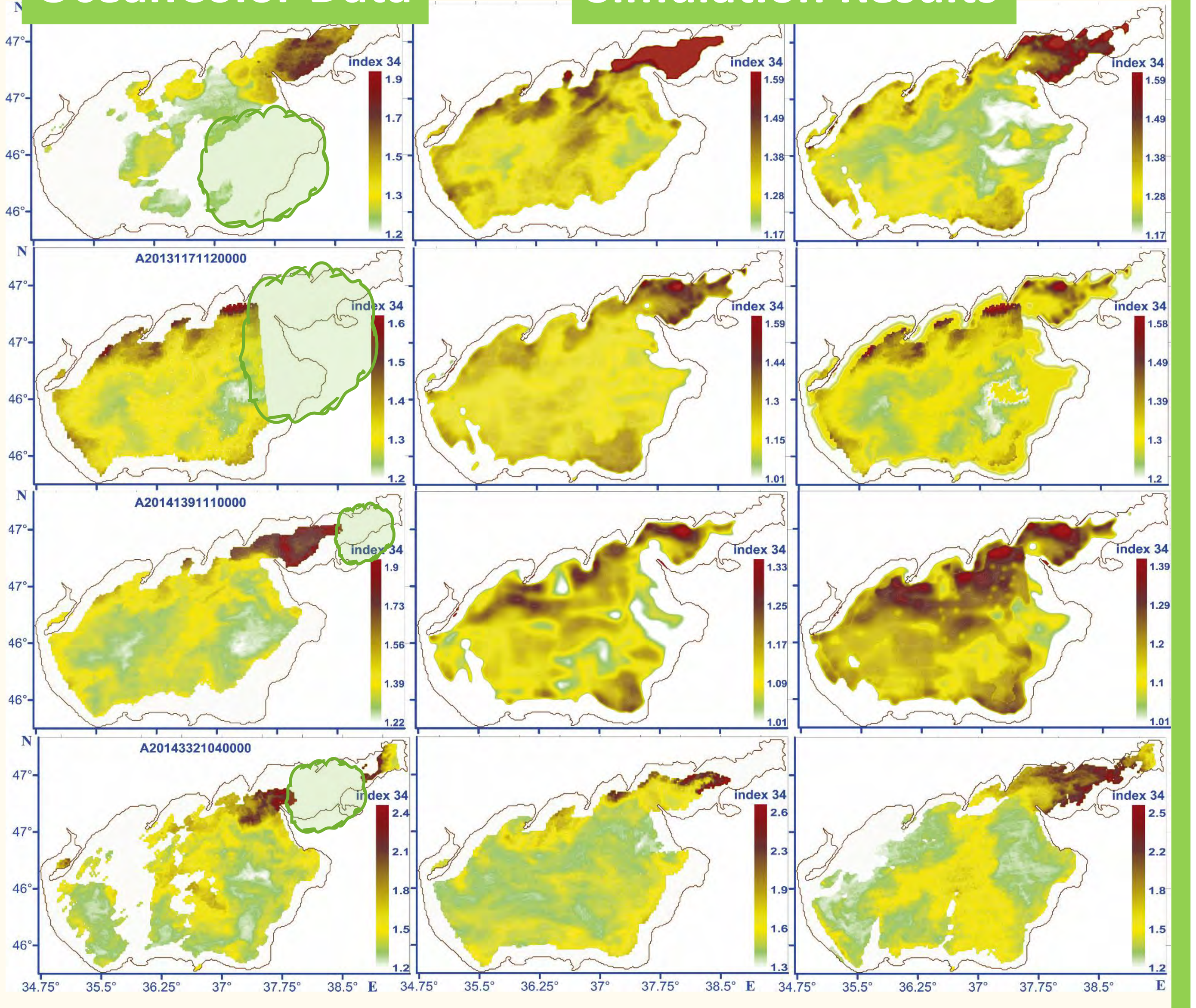


Correlation Between Observations and Modeling



Group	Period
1	April 26 - May 10, 2013
2	June 23 - June 29, 2013
3	March 21 - March 26, 2014
4	August 6 - August 10, 2014
5	July 7 - July 23, 2014
6	November 3 - November 7, 2014

OceanColor Data | Simulation Results



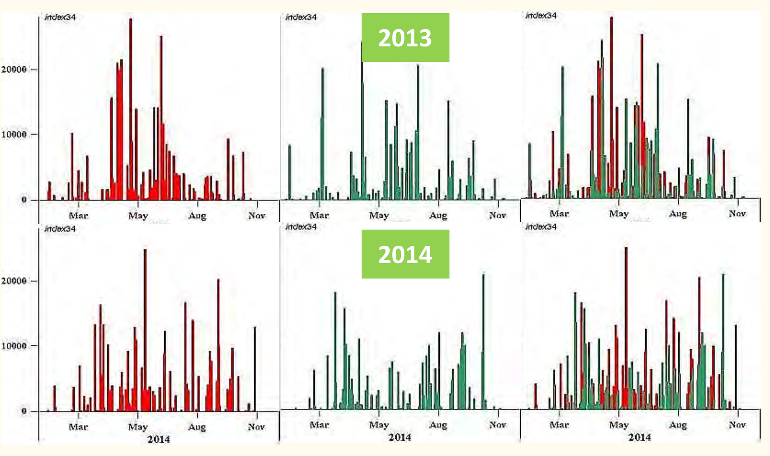


Fig.3. Histogram for the data set *MODIS- Aqua* combined with the data of *MODIS-Terra* (left) was comparison for data set of from each satellite (right)

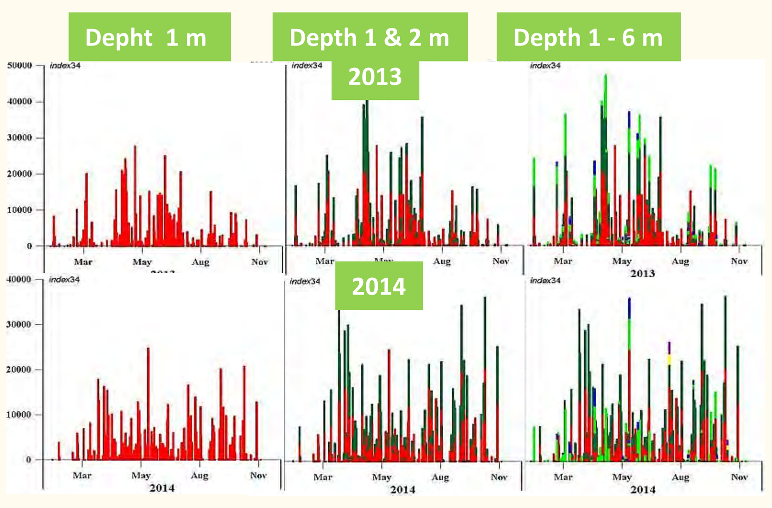
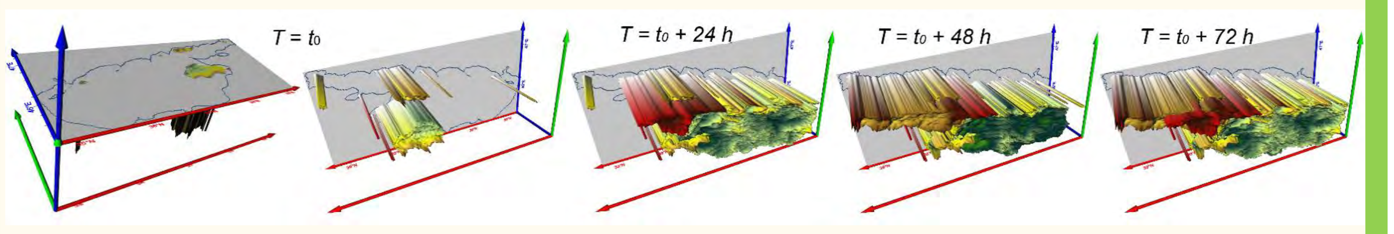
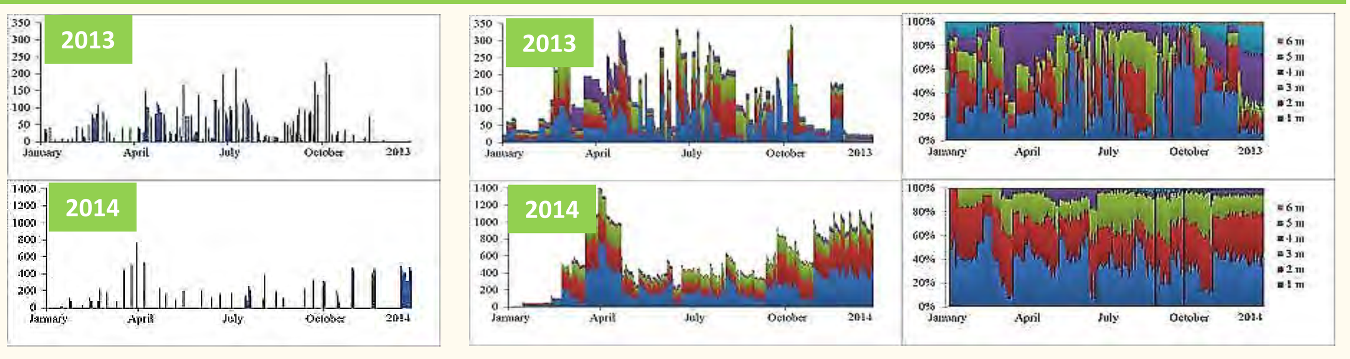


Fig.4. Histograms of the results of supplementation data of bio-optical indicators in the deep sea

The primary moment of assimilating bio-optical indicator *index*34 from the *MODIS* data (left) and simulation results after every 24 h (right)



Cumulative Distribution Bio-optical Indicators



Conclusions

- A set of applied programs designed to estimate the parameters of passive admixture in the seawaters is proposed with assimilation of observational data.
- Application of statistical analysis to the data sets led to conditioning the best assimilation choices.
- The analysis of simulation result help to detect negative changes of the sea waters and predict subject to anthropogenic impact.
- The summary result allowed to estimate to the distribution bio-optical indicators in the Sea of Azov in 2013-2014.

Work in progress:

- Improving the the assimilation algorithm
- Taking into simulation in real data
- Developing applied programm complex.

Reference

[1] Suslin, V. V. and Churilova, T. Ya. "A regional algorithm for separating light absorption by chlorophyll-a and coloured detrital matter in the Black Sea, using 480–560 nm bands from ocean colour scanners, " Int. J. Remote Sensing 37(18), 4380-400 (2016)

[2] Thuillier, G., Hersé, M., Labs, D., et al. (2003). The solar spectral irradiance from 200 to 2400 nm as measured by the SOLSPEC spectrometer from the Atlas and Eureca missions. Solar Physics 214: 1.

[3] Kalman, R. E. "A new approach to linear filtering and prediction problems," J. Basic Eng. 83D:95-108 (1960).

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