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Effect of the form of the error correlation functions on the uncertainty in the estimation of atmospheric aerosol distribution when using spatial-temporal optimal interpolation

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INTRODUCTION & AIM

A common approach to estimate the spatial-temporal distribution of atmospheric species properties is data assimilation. This comprises methods to combine information from different sources for obtaining the best estimate of a system state. All data assimilation techniques require knowing data error statistics. Spatial-temporal optimal interpolation (STOI) is a relatively simple and computationally cheap non-sequential method. In the optimal interpolation method, error correlations can be modeled with analytical functions on the base of the gathered data. In the present work, we investigate the effect of the form of the error correlation functions on the uncertainty in the estimate of aerosol optical depth (AOD) when using the STOI technique.

METHOD

STOI is based on estimation theory equations. The assimilation problem is to find the best estimate of the required parameter given the measurements made, together with appropriate prior information (background). Weight coefficients are chosen so as to minimize the mean square error in the estimate. The method utilizes observation error covariance and background error covariance.

$$\mathbf{x}^a = \mathbf{x}^b + \mathbf{K}(\mathbf{y} - \mathbf{H}\mathbf{x}^b)$$

$$\mathbf{K} = \mathbf{B}\mathbf{H}^T(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1}$$

$\mathbf{x}^a$ is a vector containing estimated values at a regular grid

$\mathbf{x}^b$ is a vector containing background values at a regular grid

$\mathbf{y}$ is a vector containing values of observations

$\mathbf{K}$ is a matrix containing weighting coefficients

$\mathbf{H}$ is an observation operator providing the link between observation space and background space

$\mathbf{B}$ is a covariance matrix of background errors

$\mathbf{R}$ is a covariance matrix of observational errors

We used AOD observations at 86 AERONET sites in Europe. AERONET is a global network of ground-based sun-sky-lunar radiometers. We obtained the background field using a chemical transport model GEOS-Chem. We calculated daily mean AOD at three wavelengths over Europe for 2015-2016. We modeled spatial and temporal correlation coefficients by exponential functions using the least squares method on the basis of calculated spatial and temporal covariances. Then we changed arguments of the exponential functions to make the correlation curves to change there form. We validated obtained estimates by comparison with independent observations at AERONET stations Granada, Lille and Minsk.

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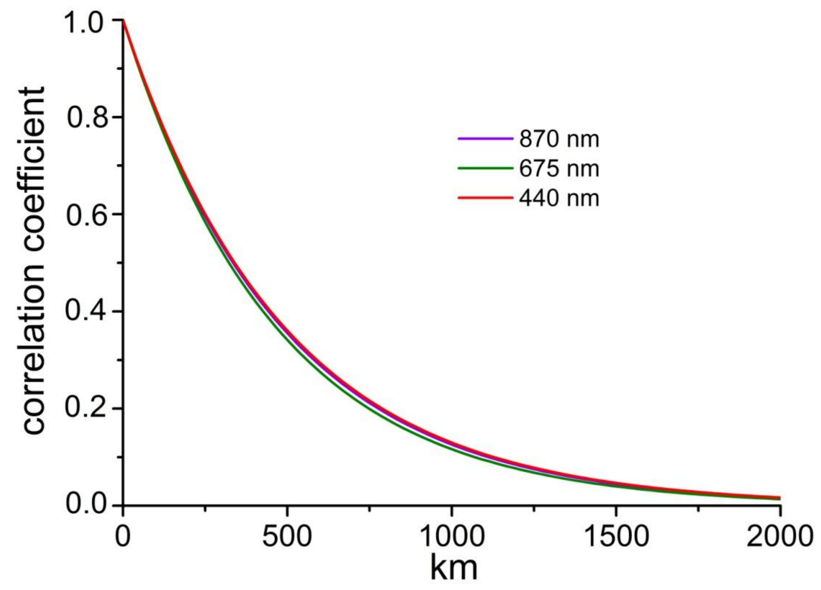
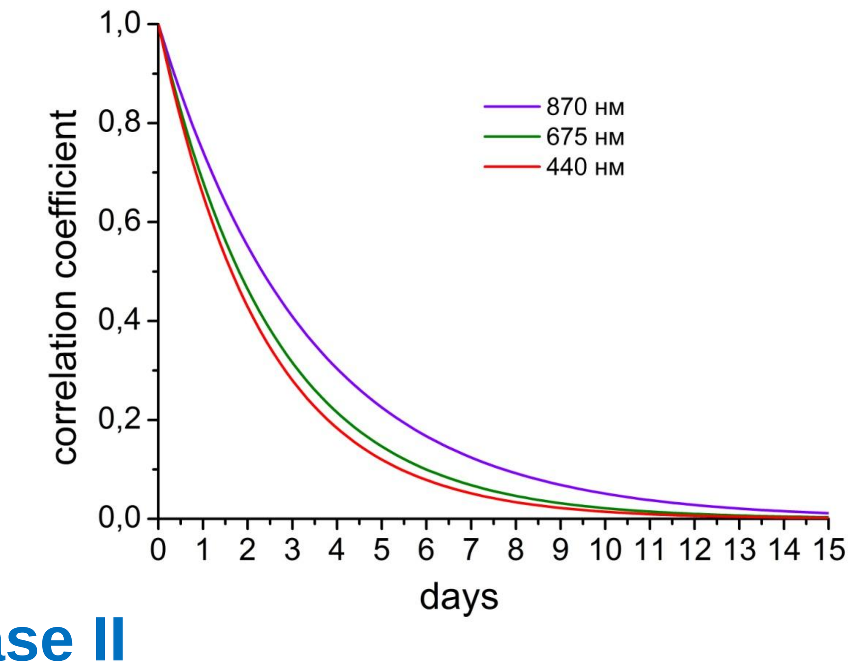
RESULTS

Case I

Correlation coefficients are modeled by exponential functions using the least squares method (d is the distance, t is time interval)

	440 n	675 nm	870 nm	Averaged
Spatial	exp(-0.00207d)	exp(-0.00215d)	exp(-0.00204d)	
Temporal	exp(-0.298t)	exp(-0.384t)	exp(-0.424t)	
Reduction in RMSE				
Granada Lille Minsk	54 % 18 % 24 %	61 % 13 % 17 %	62 % 14 % 16 %	**59 %** **15 %** **19 %**





Case II

Increased correlation coefficients: estimates are closer to the observations

	440 n	675 nm	870 nm	Averaged
Spatial	exp(-0.0015d)	exp(-0.0015d)	exp(-0.0015d)	
Temporal	exp(-0.25t)	exp(-0.335t)	exp(-0.375t)	
Reduction in RMSE				
Granada Lille Minsk	53 % 18 % 24 %	61 % 13 % 19 %	62 % 14 % 19 %	**59 %** **15 %** **21%**

Case III

Decreased correlation coefficients: estimates are closer to the model output

	440 n	675 nm	870 nm	Averaged
Spatial	exp(-0.00275d)	exp(-0.00325d)	exp(-0.00375d)	
Temporal	exp(-0.55$t^{0.6}$)	exp(-0.6$t^{0.7}$)	exp(-0.625$t^{0.725}$)	
Reduction in RMSE				
Granada Lille Minsk	55 % 19 % 21 %	62 % 14 % 7 %	63 % 13 % -7 %	**60 %** **15 %** **7 %**

CONCLUSION

We investigate the effect of the form of the error correlation functions on the uncertainty in the estimate when using the STOI technique. We use exponential functions to model correlation curves. The results show that a ±15-25% change of the argument has little effect on RMSE at the estimation points where observations are dense (Granada and Lille). STOI estimations are tentative to the form of the correlation curves at the points where observations are sparse (Minsk). The accuracy of STOI is slightly better with increased correlation coefficients (Case II).