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Generating wind fields that honour point observations and physical conservation laws

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Wind exhibits a strong spatial and temporal variability. In the application of lake modelling, these features are important for simulating water flows and stratification correctly, as mean and variance of wind speed determine the input of momentum into the lake. This makes a mere interpolation of point measurements an unsuitable method for producing model input.

Additionally to concrete point measurements, more subtle aspects of wind fields are to be reproduced. It follows from the fact that wind vectors represent moving air that a wind field has to be divergency-free in order to be mass-conservative. Further, a temporal sequence of wind fields has to comply with the Navier-Stokes equation in order to conserve momentum.

All these constraints can be met by representing the conditioned wind field as a linear combination of unconditioned, normally distributed random fields that individually possess the same spatial covariance structuref as observed wind fields. The aim of having the same covariance structure in the conditioned wind field is formulated as an optimization problem with respect to the weights used in the linear combination. With the help of Quadratic Programming (QP) and exploiting the convexity of the problem, feasible solutions can easily be found. In this QP problem, observations become linear constraints. Conservation laws can be incorporated by introducing control volumes in a similar fashion as they are used in fluid mechanics. Budgets of flows through these control volumes become integral conditions in the QP problem.

The applicability of the approach will be shown using an artificial example and real-world data measured on shore and on a moving boat on Lake Constance.